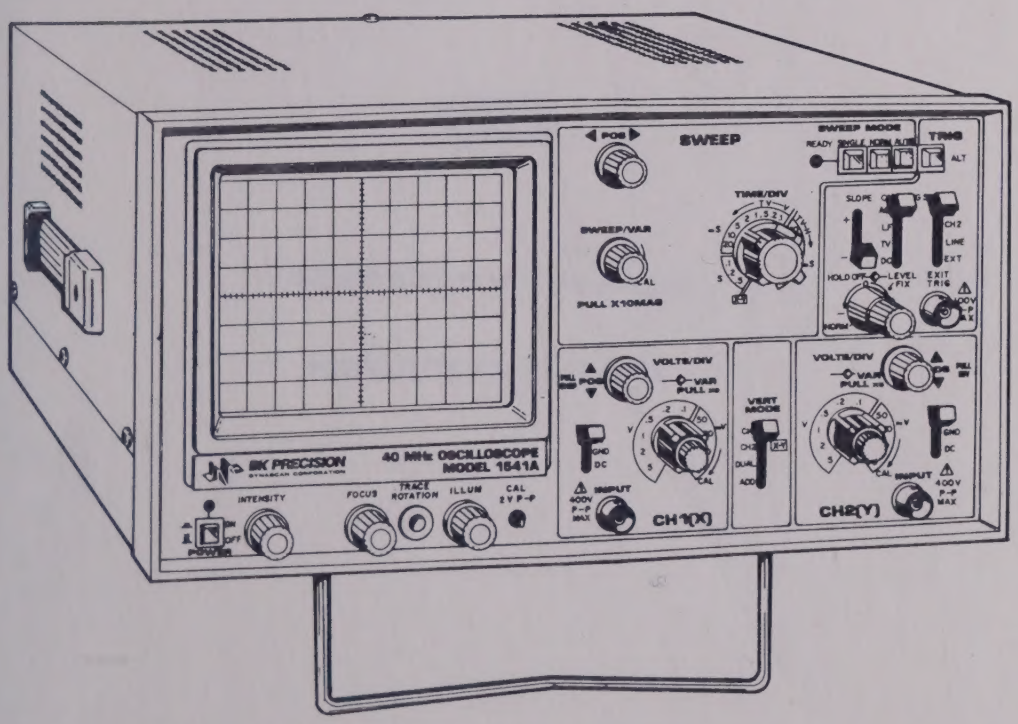
INSTRUCTION MANUAL

BK PRECISION
DYNASCAN CORPORATION

MODEL 1541A

40 MHz DUAL-TRACE OSCILLOSCOPE



BK PRECISION
DYNASCAN CORPORATION

SPECIFICATION TITTLE

METROLOGY CALIBRATION PROCEDURE
FOR THE

BK PRECISION 1541A

GTE

EQUIPMENT SERVICES CENTER

METROLOGY DEPARTMENT

PRODUCTION ENGINEERING - ESC		
Prepared by		Date
Approved by Equipment Services Superintendetedent		Date
Approved by Equipment Services Manager		Date
Issue	Spec. No. [redacted] MCP0654	Sh. 01 of

ISSUE STATUS SPECIFICATION

EPC 900.

RELATED SPECIFICATIONS	CURRENT ISSUES & STATUS
EPC 900.	
EPC 900. -EPS	N/A
EPC 900. -TRS	N/A
EPC 900. -RPS	N/A
EPC 900. -XRF	N/A
EPC 900. -PSS	N/A
EPC 900.000-CAL	

METROLOGY CALIBRATION PROCEDURE

GTE
WEST
CALIFORNIA
EQUIPMENT SERVICES
METROLOGY

Prepared by

Technically Validated by

Approved by

STANDARDS LIST

NOTE: The equipment list below reflects the standards recommended by the calibration procedure of the UUT. Devatations from the recommended standards will be documented on this sheet.

RECOMMENDED STANDARDS	STANDARDS USED

TEST INSTRUMENT SAFETY

WARNING

Normal use of test equipment exposes you to a certain amount of danger from electrical shock because testing must often be performed where exposed high voltage is present. An electrical shock causing 10 milliamps of current to pass through the heart will stop most human heartbeats. Voltage as low as 35 volts dc or ac rms should be considered dangerous and hazardous since it can produce a lethal current under certain conditions. Higher voltage poses an even greater threat because such voltage can more easily produce a lethal current. Your normal work habits should include all accepted practices that will prevent contact with exposed high voltage, and that will steer current away from your heart in case of accidental contact with a high voltage. You will significantly reduce the risk factor if you know and observe the following safety precautions:

1. Don't expose high voltage needlessly in the equipment under test. Remove housings and covers only when necessary. Turn off equipment while making test connections in high-voltage circuits. Discharge high-voltage capacitors after removing power.

2. If possible, familiarize yourself with the equipment being tested and the location of its high voltage points. However, remember that high voltage may appear at unexpected points in defective equipment.

3. Use an insulated floor material or a large, insulated floor mat to stand on, and an insulated work surface on which to place equipment; make certain such surfaces are not damp or wet.

4. Use the time-proven "one hand in the pocket" technique while handling an instrument probe. Be particularly careful to avoid contacting a nearby metal object that could provide a good ground return path.

5. When using a probe, touch only the insulated portion. Never touch the exposed tip portion.

6. When testing ac powered equipment, remember that ac line voltage is usually present on some power input circuits such as the on-off switch, fuses, power transformer, etc. any time the equipment is connected to an ac outlet, even if the equipment is turned off.

7. Some equipment with a two-wire ac power cord, including some with polarized power plugs, is the "hot chassis" type. This includes most recent television receivers and audio equipment. A plastic or wooden cabinet insulates the chassis to protect the customer. When the cabinet is removed for servicing, a serious shock hazard exists if the chassis is touched. Not only does this present a dangerous shock hazard, but damage to test instruments or the equipment under test may result from connecting the ground lead of most test instruments (including this oscilloscope) to a "hot chassis". To make measurements in "hot chassis" equipment, always connect an isolation transformer between the ac outlet and the equipment under test. The **B & K-Precision** Model TR-110 or 1604 Isolation Transformer, or Model 1653 or 1655 AC Power Supply is suitable for most applications. To be on the safe side, treat all two-wire ac powered equipment as "hot chassis" unless you are sure it has an isolated chassis or an earth ground chassis.

8. Never work alone. Someone should be nearby to render aid if necessary. Training in CPR (cardio-pulmonary resuscitation) first aid is highly recommended.

Instruction Manual

for

BK PRECISION
DYNASCAN CORPORATION

Model 1541A

40 MHz

Dual-Trace Oscilloscope

BK PRECISION
DYNASCAN CORPORATION

6460 W. Cortland St. • Chicago, IL 60635
312-889-8870

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FEATURES

HIGH FREQUENCY FEATURES

Wide Bandwidth
Conservatively rated -3 dB bandwidth is dc to 40 MHz.

Fast Rise Time
Rise time is less than 8.8 ns.

DUAL TRACE FEATURES

Dual Trace

Model 1541A has two vertical input channels for displaying two waveforms simultaneously. Selectable single trace (either CH 1 or CH 2) or dual trace. Alternate or chop sweep selectable at all sweep rates.

Sum and Difference Capability
Permits algebraic addition or subtraction of channel 1 and channel 2 waveforms, displayed as a single trace. Useful for differential voltage and distortion measurements.

CRT FEATURES

Rectangular CRT
Rectangular CRT with large 8 x 10 centimeter viewing area. Internal 8 x 10 division graticule eliminates parallax error.

Convenience
Variable scale illumination for easy viewing in darkened area and for waveform photographs. Trace rotation electrically adjustable from front panel. 0%, 10%, 90%, and 100% markers for rise time measurements.

VERTICAL FEATURES

High Sensitivity
5 mV/div sensitivity for full bandwidth. Selectable X5 gain increases maximum sensitivity to 1 mV/div at reduced bandwidth.

Calibrated Voltage Measurements
Accurate voltage measurements (±3%) on 10 calibrated ranges from 5 mV/div to 5 V/div. Vertical gain fully adjustable between calibrated ranges.

X5 Vertical Gain Magnification
X5 magnification control increases vertical sensitivity and adds 2 mV/div and 1 mV/div calibrated vertical attenuator ranges.

SWEEP FEATURES

Calibrated Time Measurements
Accurate (±3%) time measurements. Model 1541A has 20 calibrated ranges from 0.5 s/div to 0.2 μs/div. Sweep time is fully adjustable between calibrated ranges.

X10 Sweep Magnification
Allows closer examination of waveforms, increases maximum sweep rate to 20 ns/div.

TRIGGERING FEATURES

Five Trigger Modes
Selectable automatic, normal (triggered), FIX, X-Y, or single sweep modes.

AUTO Sweep
Selectable AUTO sweep provides sweep without trigger input, automatically reverts to triggered sweep operation when adequate trigger is applied.

Triggered Sweep
Sweep remains at rest unless adequate trigger signal is applied. Fully adjustable trigger level and (+) or (-) slope.

FIX Trigger Level
Trigger level is automatically fixed on center of waveform.

X-Y Operation
Channel 1 can be applied as horizontal deflection (X-axis) while channel 2 provides vertical deflection (Y-axis).

SPECIFICATIONS

CRT:

Model:
150BYB31.

Type:
Rectangular with internal graticule.

Display Area:
8 x 10 div(1 div = 1 cm).

Accelerating Voltage:
12 kV.

Scale Illumination:
Continuously adjustable.

VERTICAL AMPLIFIERS (CH 1 and CH 2)

Sensitivity:
5 mV/div to 5 V/div.
1 mV/div to 1 V/div, X5 gain selected.

Accuracy:
5 mV/div to 5 V/div, ±3%.
X5 gain selected, ±5%.

Input Resistance:
1 MΩ ±2%.

Input Capacitance:
Approximately 30 pF.

Frequency Response:
5 mV/div to 5 V/div (X5 gain not selected):
DC: DC to 40 MHz (-3 dB).
AC: 10 Hz to 40 MHz (-3 dB).
X5 gain selected:
DC: DC to 20 MHz (-3 dB).
AC: 10 Hz to 20 MHz (-3 dB).

Rise Time:
5 mV/div to 5 V/div (X5 gain not selected):
8.8 ns.
X5 gain selected:
17.5 ns.

Crosstalk:
At least 1000:1 (60 dB) at 50 kHz.
At least 30:1 (31.5 dB) at 40 MHz.

Operating Modes:
CH 1: CH 1, single trace.
CH 2: CH 2, single trace.
DUAL: dual trace.
0.5 s/div to 1 ms/div, CHOP.
0.5 ms/div to 0.2 μs/div, ALT.
CHOP or ALT selectable at any sweep rate.
ADD: algebraic sum of CH 1 + CH 2.

Chop Frequency:
Approximately 250 kHz.

Polarity Reversal:
CH 2 only.

Maximum Input Voltage:
400 V (dc + ac peak) or 800 V ac p-p.

HORIZONTAL AMPLIFIER
(Input through channel 1 input)

X-Y mode: switch selectable using TIME/DIV switch.
CH 1: X axis.
CH 2: Y axis.

Sensitivity:
Same as vertical channel 1.

Accuracy:
Normal ±4%, X5 Gain ±6%.

Input Impedance:
Same as vertical channel 1.

Frequency Response:
DC to 2 MHz (-3 dB).

X-Y Phase Difference:
3° or less at 50 kHz.

Maximum Input Voltage:
Same as vertical channel 1.

HORIZONTAL AMPLIFIER
(Input through EXT TRIG input)

EXT Horizontal Mode:
Trace swept by external horizontal signal. Vertical axis modes CH 1, CH 2, DUAL, and ADD.

Sensitivity:
Approximately 0.1 V/div.

Bandwidth:
DC to 2 MHz (-3 dB).

Phase Difference:
3° or less at 50 kHz.

Maximum Voltage:
100 V (dc + ac peak) to 1 kHz.

SWEEP SYSTEM

Sweep Speed:
0.2 µs/div to 0.5 s/div in 1-2-5 sequence, 20 steps. Vernier control provides fully adjustable sweep time between steps.

Accuracy:
±3%.

Sweep Magnification:
10X, ±5% (±8% for 0.2 µs/div and 0.5 µs/div).

Linearity (for eight center divisions of sweep):
Norm ±3%.
X10 MAG ±5% (±8% for 0.2 µs/div and 0.5 µs/div).

Holdoff:
Continuously adjustable from NORM to 10 times normal.

TRIGGERING

Trigger Modes:
AUTO (free run), NORM, FIX, X-Y, SINGLE.

Trigger Source:
CH 1, CH 2, ALT, LINE, EXT.

Trigger Coupling:

AC	10 Hz to 40 MHz.
DC	DC to 40 MHz.
HF REJ	10 Hz to 50 kHz.
TV	Line automatically selected at 50 µs/div and faster. Frame automatically selected at 0.1 ms/div and slower.

Trigger Sensitivity:

COUPLING	BANDWIDTH	INT	EXT
DC	DC - 10 MHz DC - 40 MHz	0.5 div 1.5 div	100 mV 200 mV
AC	Same as DC except increased attenuation below 10 Hz		
LF (HF REJ)	Same as AC except increased attenuation above 50 kHz.		
TV		2 div	200 mV
AUTO	Same as AC except lower limit is 50 Hz.		
FIX, ALT	Same as AC plus 0.5 div for signal of duty cycle 20:80 and repetition frequency of 50 Hz to 40 MHz.		

External Trigger:

Input Impedance:
1 MΩ ±2%, approximately 30 pF.

Maximum Input Voltage:
100 V (dc + ac peak) to 1 kHz.

OTHER SPECIFICATIONS

Calibrating Voltage:
1 kHz Positive Square Wave (±5%), 2 V p-p (±2%). Duty cycle of 50% ±2%.

Intensity Modulation:

Input Signal:
TTL level, intensity decreasing with more positive levels.

Input Impedance:
Approximately 5 kΩ.

Usable Frequency Range:
DC to 5 MHz.

Maximum Input Voltage:
100 V (dc + ac peak) to 1 kHz.

CH 1 Output (on rear panel):

Output Voltage:
50 mV/div (into 50-ohm load).

Output Impedance:
Approximately 50 ohms.

Frequency Response:
5 mV/ div to 5 V/div:
100 Hz to 40 MHz, -3 dB, into 50 Ω.
1 mV/div and 2 mV/div:
100 Hz to 15 MHz, -3 dB, into 50 Ω.

Trace Rotation:
Electrical, front panel adjustable.

Power Requirements:
100 V/120 V/220 V/230 V/240 V ±10%, 50/60 Hz, approximately 35 W.

Dimensions:
310 x 170 x 460 mm (13.4 x 5.7 x 15.0").

Weight:
7.1 kg (17.6 lb).

Operating Environment:
+10° to +35° C, 85% maximum relative humidity for full specifications.
0° to +40° C, 85% maximum relative humidity, full operating range.

SUPPLIED ACCESORIES:
Two 10:1/Direct Probes.
Instruction Manual.
Schematic Diagram and Parts List.

OPTIONAL ACCESSORIES:
10:1 Probe, PR-45.
100:1 Probe, PR-100.

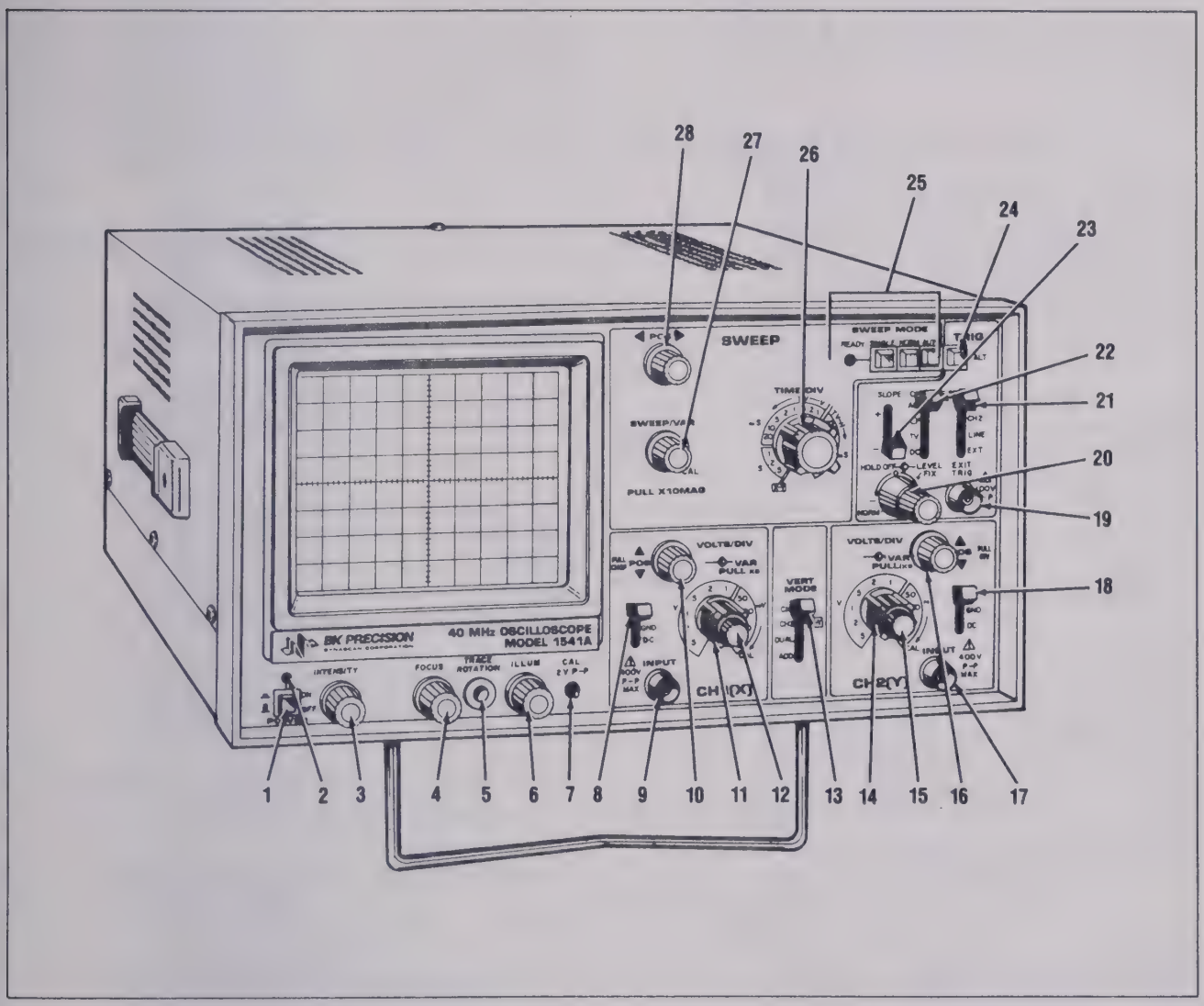

Fig. 1. Front Panel Controls And Indicators.

FRONT PANEL CONTROLS AND INDICATORS

CRT CONTROLS

1. **POWER Switch.** Turns oscilloscope power on and off.

2. **POWER Indicator.** Lights when oscilloscope is on.

3. **INTENSITY Control.** Adjusts brightness of trace.

4. **FOCUS Control.** Adjusts sharpness of trace.

5. **TRACE ROTATION Control.** Screwdriver adjustment used to adjust trace to optimum horizontal position.

6. **Scale ILLUMination Control.** Adjusts intensity of oscilloscope scale. When control is fully counterclockwise, oscillo-

scope scale illumination is off. Clockwise rotation of the control increases the illumination of the graticule scale.

7. **CAL 2 V p-p Terminal.** This terminal provides a 1 kHz, 2-volt peak-to-peak square wave signal. This is useful for probe compensation adjustment and a general check of oscilloscope calibration accuracy.

CHANNEL 1 CONTROLS

8. **AC-GND-DC Switch.** Three-position lever switch which operates as follows:
   - **AC:** Channel 1 input signal is capacitively coupled; dc component is blocked.
   - **GND:** Opens signal path and grounds input to vertical amplifier. This provides a zero-volt base line, the position of which can be used as a reference when performing dc measurements.
   - **DC:** Direct coupling of channel 1 input signal; both ac and dc component of signal produce vertical deflection.

9. **CH 1 (X) Jack.** Vertical input for channel 1. X axis input for X-Y operation.

10. **↕CH1 POSition, PULL CHOP Control.**
    - **↕CH 1 POSition:** Rotation adjusts vertical position of channel 1 trace.
    - **PULL CHOP (Push-Pull Switch):** Selects chop method of dual-trace display. When this control is pulled out and dual-trace is selected, both waveforms will be displayed simultaneously, regardless of **TIME/DIV** or **ALT** control settings. When this control is pushed in and dual-trace is selected, the display method (chop or alternate) is automatically selected by the **TIME/DIV** control (unless overridden by the **ALT** switch).

11. **VOLTS/DIV Control.** Vertical attenuator for channel 1. Provides step adjustment of vertical sensitivity. When channel 1 **VAR** control is set to **CAL**, vertical sensitivity is calibrated in 10 steps from 5 mV/div to 5 V/div in a 1-2-5 sequence. In X-Y operation, this control provides step adjustment of X-axis sensitivity.

12. **VARiable, PULL X5 Control.**
    - **VARiable:** Rotation provides vernier adjustment of channel 1 vertical gain. In the fully clockwise (**CAL**) position, the vertical attenuator is calibrated. In X-Y operation this control becomes the vernier X-axis gain control.
    - **PULL X5 (Push-Pull Switch):** Multiplies channel 1 vertical gain five times; for example, 5 mV/div sensitivity becomes 1 mV/div.

13. **VERTical MODE Switch.**
    - **CH 1:** Only the input signal to channel 1 is displayed on the CRT.
    - **CH 2/X-Y:** Only the input signal to channel 2 is displayed on the CRT. Also, used in conjunction with **TIME/DIV** and trigger **SOURCE** switch to select **X-Y** operating mode.
    - **DUAL:** The input signal to channel 1 and channel 2 are displayed simultaneously on two traces.
    - **ADD:** The input from channel 1 and channel 2 are algebraically summed and displayed as a single signal. When the **CH 2 INV** function is activated, the input from channel 2 is subtracted from channel 1 and the difference is displayed as one signal.

CHANNEL 2 CONTROLS

14. **VOLTS/DIV Control.** Vertical attenuator for channel 2. Provides step adjustment of vertical sensitivity. When channel 2 **VAR** control is set to **CAL**, vertical sensitivity is calibrated in 10 steps from 5 mV/div to 5 V/div in a 1-2-5 se-

quence. In X-Y operation, provides step adjustment of Y-axis sensitivity.

15. **VARiable, PULL X5 Control.**

VARiable:

Rotation provides vernier adjustment of channel 2 vertical sensitivity. In the fully clockwise (**CAL**) position, the attenuator is calibrated. In X-Y operation this control becomes the vernier Y-axis gain control.

PULL X5 (Push-Pull Switch):

Multiplies channel 1 vertical gain five times; for example, 5 mV/div sensitivity becomes 1 mV/div.

16. **↕CH2 POSition, PULL INVert Control.**

↕CH2 POSition:

Rotation adjusts vertical position of channel 2 trace. In X-Y operation, rotation adjusts vertical position of display.

PULL INVert (Push-Pull Switch):

Selects inverse of normal polarity of channel 2 signal; inverted polarity when pulled out, normal polarity when pushed in.

17. **CH 2 (Y) Jack.** Vertical input for channel 2. Y-axis input in X-Y operation.

18. **AC-GND-DC Switch.** Three-position lever switch which operates as follows:

AC:

Channel 2 input signal is capacitively coupled; dc component is blocked.

GND:

Opens signal path and grounds input to vertical amplifier. This provides a zero-volt base line, the position of which can be used as a reference when performing dc measurements.

DC:

Direct coupling of channel 2 input signal; both ac and dc component of signal produce vertical deflection.

TRIGGERING CONTROLS

19. **EXT TRIG Jack.** External trigger input for single and dual-trace operation. Also serves as sweep input for external horizontal operation.

20. **TRIGger LEVEL, HOLD OFF Control.**

TRIGger LEVEL:

Trigger level adjustment, determines point on the triggering waveform where the sweep is triggered. Rotation in the (-) direction selects a more negative point of triggering, and rotation in the (+) direction selects a more positive point of triggering. When the control is rotated fully counterclockwise (**FIX**), the **FIX** triggering mode is selected. In the **FIX** triggering mode, the trigger threshold is automatically set at the center of the waveform.

HOLD OFF:

Rotation of control adjusts holdoff time (trigger inhibit period beyond sweep duration). When control is rotated fully counterclockwise, holdoff is set to **NORM.** Holdoff period increases progressively with clockwise rotation to a maximum of about 10 times normal.

21. **TRIGger SOURCE Switch.** Selects source of sweep trigger. Four position lever switch with the following positions:

CH 1:

Channel 1 signal becomes sweep trigger for dual-trace operation (for single-trace operation, the channel displayed is the trigger signal unless the **LINE** or **EXT** position is selected).

CH 2:

Channel 2 signal becomes sweep trigger for dual-trace operation (for single trace operation, the channel displayed is the trigger signal unless the **LINE** or **EXT**, position is selected).

LINE:

Signal derived from the input line voltage (50/60 Hz) becomes trigger.

EXT:

Signal from **EXT TRIG** jack becomes sweep trigger.

22. **TRIGger COUPLING Switch.** Selects trigger coupling. Four-position lever switch with the following positions:

AC:
Trigger is capacitively coupled; dc component is blocked.

HF REJ:
Trigger is coupled through low pass filter. Frequencies above 40 kHz are attenuated.

TV:
Vertical or horizontal sync pulses are selected. When sweep speeds of 0.1 ms/div or slower are selected, vertical sync pulses are selected. When sweep speeds of 50 µs/div or faster are selected, horizontal sync pulses are selected.

23. **TRIGger SLOPE (-) Switch.** Two-position switch selects negative going or positive going trigger slope. When the switch is in (-) position, negative going (-) slope is selected and when the switch is in the (+) position, positive-going (+) slope is selected as the triggering point.

24. **ALT TRIG Switch.** Selects alternate trigger and alternate display mode when the switch is engaged and dual-trace display is selected. In the alternate trigger mode, the input signals alternate as the trigger source and triggering is impossible unless both input signals are of adequate level to trigger the sweep. In the alternate display mode when dual-trace display is selected, the waveforms will be displayed in an alternating fashion. However, if **PULL CHOP** control is in the pulled out position, **CHOP** display mode is selected (the **PULL CHOP** control overrides both the **TIME/DIV** and **ALT** setting) and the display cannot be synchronized since the chopping signal becomes the trigger source.

SWEEP CONTROLS

25. **SWEEP MODE Switches.** Three mechanically interactive switches used to select the desired triggering mode as follows:

AUTO:
Selects automatic triggering mode. Generates sweep (free runs) in absence of trigger; automatically reverts to triggered sweep operation when adequate trigger signal is present.

NORM:
Selects normal triggered sweep operation, which generates a sweep only when adequate trigger signal is present. When the oscilloscope is set up for multiple trigger sources (dual-trace display with **ALT** triggering selected), both channels must have adequate trigger signals to obtain a sweep.

SINGLE:
Selects single sweep operation. For dual-trace display, single sweep requires **CHOP** method of display; do not select **ALT**. A single sweep will begin when the next sync trigger occurs. After a single sweep, **SINGLE** must be pressed again to enable next single sweep. Indicator (**READY** LED) lights to show that single sweep operation is ready for triggering. Lights when **SINGLE** switch is operated and remains lit until one sweep is completed.

26. **TIME/DIV Control.** Provides step selection of sweep rate. When the sweep time **VAR** control is set to the **CAL** position, sweep rate is calibrated. Control has 20 steps from 0.2 µs/div to 0.5 s/div, in a 1-2-5 sequence. When control is rotated fully counterclockwise, X-Y/EXT HOR mode of operation is selected. If control is in **X-Y** position and trigger **SOURCE** switch is set to **CH 1/X-Y** position, oscilloscope is in X-Y operating mode. If control is in **X-Y** position and trigger **SOURCE** switch is set to **EXT** position, the signal connected to **EXT TRIG** jack controls sweep.

27. **SWEEP/VARiable, PULL X10 MAG Control.**

SWEEP/VARiable.:
Rotation of this control is the vernier adjustment for sweep rate. When the control is rotated fully clockwise (**CAL**), the sweep rate is calibrated.

PULL X10 MAG (Push-Pull Switch):
Selects ten times sweep magnification when pulled out (**X10 MAG**),

normal when pushed in. Expands sweep and increases maximum sweep rate to 20 ns/div.

28. ◂▸ **POSition Control.** Horizontal position control. Adjusts horizontal position of display in all operating modes.

REAR PANEL CONTROLS

29. **GND Terminal.** Oscilloscope chassis ground and earth ground via 3-wire ac power cord.

30. **CH 1 OUT Jack.** Output terminal where sample of channel 1 signal is available. Amplitude is 50 millivolts per division of vertical deflection seen on CRT when terminated into 50 ohms. Output impedance is 50 ohms.

31. **Z AXIS INPUT Jack.** Input jack for intensity modulation of CRT electron beam. TTL compatible (5 volts p-p sensitivity). Positive signal levels decrease intensity.

32. **Fuse Holder.** Contains line fuse.

33. **Tilt Stand (not shown).**

34. **Feet/Cord Wrap.**

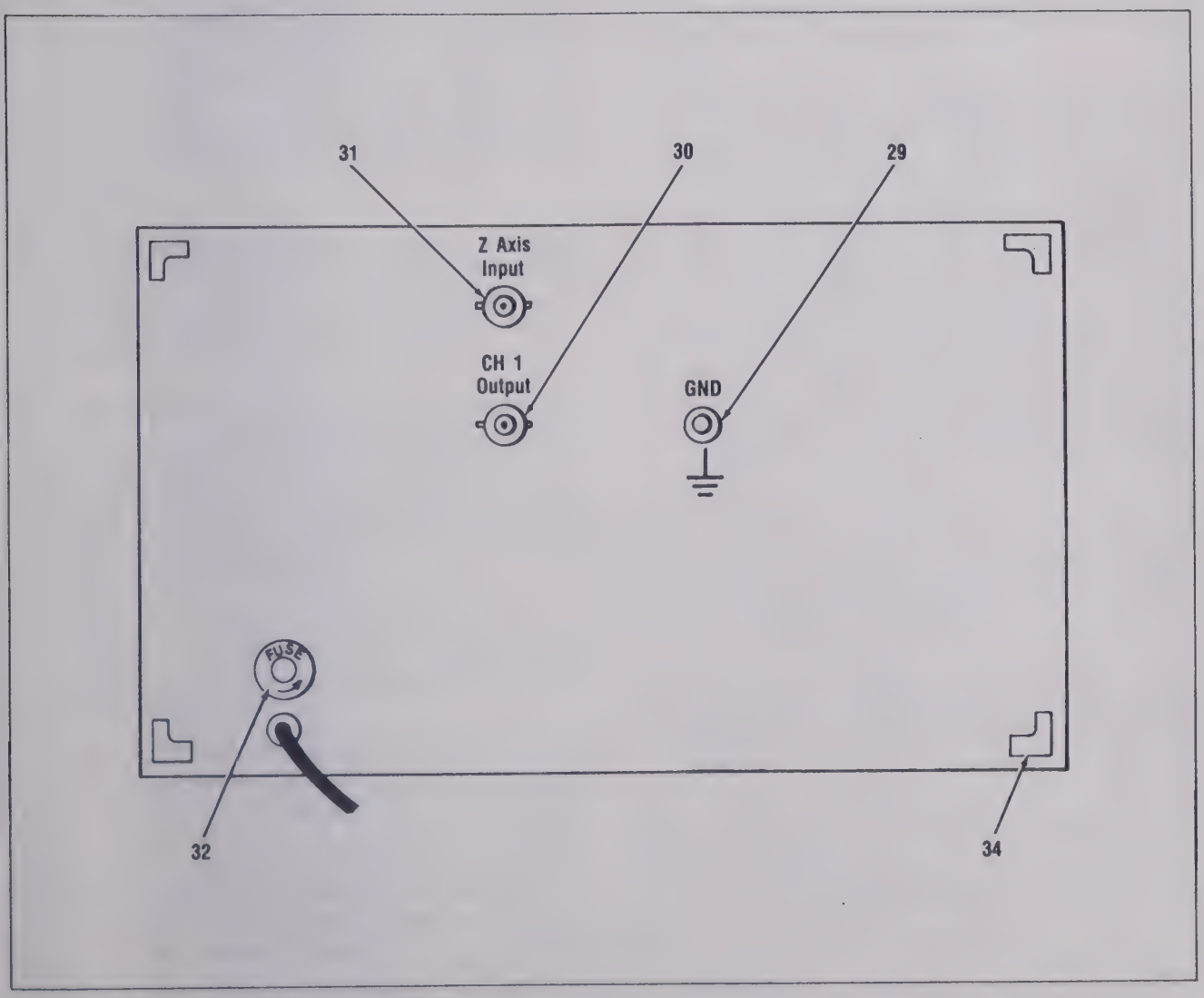

Fig. 2. Rear Panel Controls.

SAFETY PRECAUTIONS

WARNING

The following precautions must be observed to help prevent electric shock.

1. *When the oscilloscope is used to make measurements in equipment that contains high voltage, there is always a certain amount of danger from electrical shock. The person using the oscilloscope in such conditions should be a qualified electronics technician or otherwise trained and qualified to work in such circumstances. Observe the TEST INSTRUMENT SAFETY recommendations listed on the inside front cover of this manual.*

2. *Do not operate this oscilloscope with the case removed unless you are a qualified service technician. High voltage up to 12,000 volts is present when the unit is operating with the case removed.*

3. *The ground wire of the 3-wire ac power plug places the chassis and housing of the oscilloscope at earth ground. Use only a 3-wire outlet, and do not attempt to defeat the ground wire connection or float the oscilloscope; to do so may pose a great safety hazard.*

4. *Special precautions are required to measure or observe line voltage waveforms with any oscilloscope. Use the following procedure:*

   a. *Do not connect the ground clip of the probe to either side of the line. The clip is already at earth ground and touching it to the hot side of the line may "weld" or "disintegrate" the probe tip and cause possible injury, plus possible damage to the scope or probe.*

   b. *Insert the probe tip into one side of the line voltage receptacle, then the other. One side of the receptacle should be "hot" and produce the waveform. The other side of the receptacle is the ac return and no waveform should result.*

EQUIPMENT PROTECTION PRECAUTIONS

CAUTION

The following precautions will help avoid damage to the oscilloscope.

1. Never allow a small spot of high brilliance to remain stationary on the screen for more than a few seconds. The screen may become permanently burned. A spot will occur when the scope is set up for X-Y operation and no signal is applied. Either reduce the intensity so the spot is barely visible, apply signal, or switch back to normal sweep operation. It is also advisable to use low intensity with **AUTO** triggering and no signal applied for long periods. A high intensity trace at the same position could cause a line to become permanantly burned onto the screen.

2. Do not rest objects on top of the oscilloscope or otherwise obstruct the ventilating holes in the case, as this will increase the internal temperature.

3. Excessive voltage applied to the input jacks may damage the oscilloscope. The maximum ratings of the inputs are as follows:

   CH 1 and CH 2:
   800 V p-p; 400 V dc + ac peak.
   EXT TRIG:
   100 V dc + ac peak.
   Z AXIS INPUT:
   50 V dc + ac peak.

   Never apply external voltage to oscilloscope output jacks.

4. Always connect a cable from the ground terminal of the oscilloscope to the chassis of the equipment under test. Without this precaution, the entire current for the equipment under test may be drawn through the probe clip leads under certain circumstances. Such conditions could also pose a safety hazard, which the ground cable will prevent.

5. The probe ground clips are at oscilloscope ground and should be connected only to the common of the equipment under test. To measure with respect to any point other than the common, use CH 1 - CH 2 subtract operation (**ADD** mode and **CH 2 INV**), with the channel 1 probe to the point of measurement and the channel 2 probe to the point of reference. Use this method even if the reference point is a dc voltage with no signal.

OPERATING TIPS

The following recommendations will help obtain the best performance from the oscilloscope.

1. Always use the probe ground clips for best results, attached to a circuit ground point near the point of measurement. Do not rely solely on an external ground wire in lieu of the probe ground clips as undesired signals may be induced.

2. Avoid the following operating conditions:
   a. Direct sunlight.
   b. High temperature and humidity.
   c. Mechanical vibration.
   d. Electrical noise and strong magnetic fields, such as near large motors, power supplies, transformers, etc.

3. Occasionally check trace rotation, probe compensation, and calibration accuracy of the oscilloscope using the procedures found in the MAINTENANCE section of this manual.

4. Terminate the output of a signal generator into its characteristic impedance to minimize ringing, especially if the signal has fast edges such as square waves or pulses. For example, the typical 50 Ω output of a square wave generator should be terminated into an external 50 Ω terminating resistor and connected to the oscilloscope with 50 Ω coaxial cable.

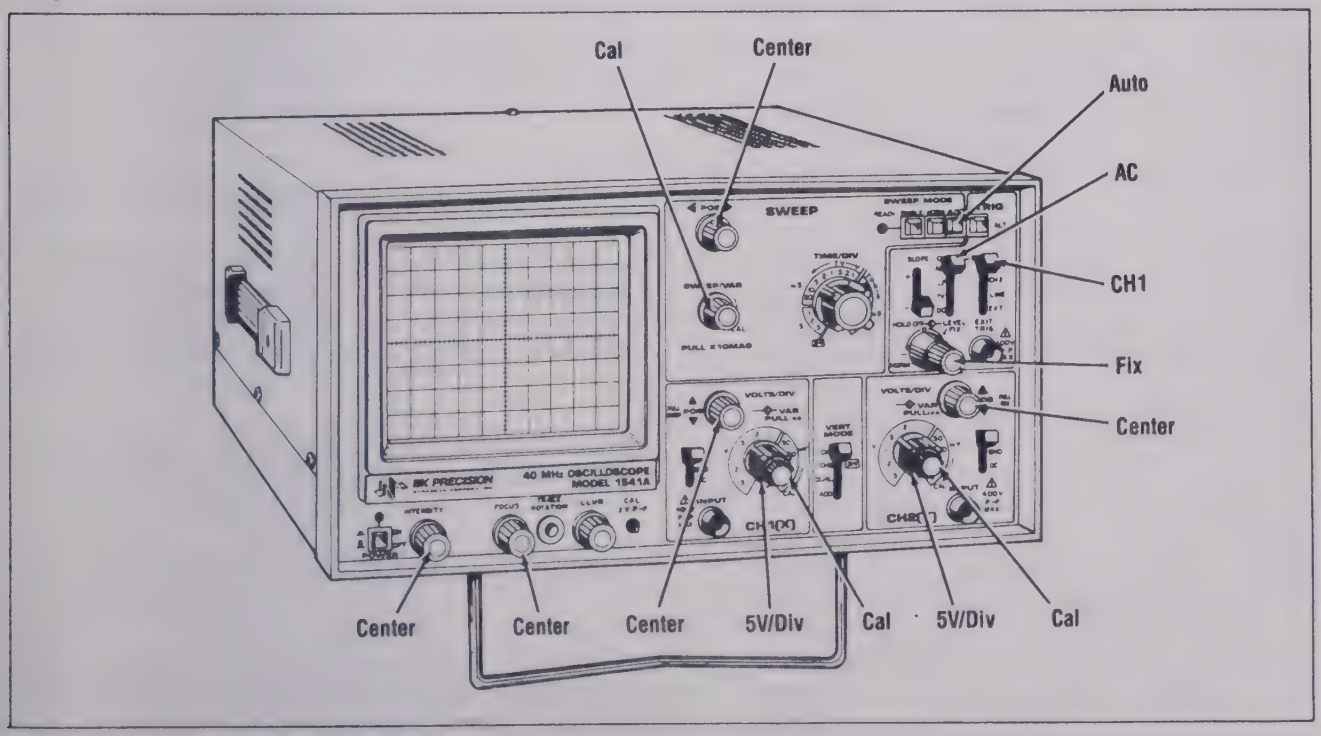

Fig. 3. Initial Control Settings.

5. Probe compensation adjustment matches the probe to the input of the scope. For best results, compensation should be adjusted initially, then the same probe always used with the same channel. Probe compensation should be readjusted when a probe from a different oscilloscope is used.

INITIAL STARTING PROCEDURE

Until you familiarize yourself with the use of all controls, the settings shown in Fig. 3 may be used as a reference point to obtain a trace on the CRT in preparation for waveform observation.

1. Engage the **POWER** switch; the unit will be turned on and the pilot light will be illuminated. Adjust scale illumination level with the **ILLUM** control. When the control is turned fully clockwise, the scale is illuminated at full brightness.

2. The controls should be set as follows; **VERT MODE** to **CH 1**, **SWEEP MODE** to **AUTO**, and **TRIG SOURCE** to **CH 1**.

3. A trace should appear on the CRT. Adjust the trace brightness with the **INTEN** control and the trace sharpness with the **FOCUS** control.

SINGLE TRACE DISPLAY

Either channel 1 or channel 2 may be used for single-trace operation. The advantage of using channel 2 is that the waveform on the display can be inverted if desired with the **PULL INV** switch.

1. Perform the steps of the "Initial Starting Procedure" with the **VERT MODE** switch set to **CH 2**.

2. Connect the probe to the **CH 2 (Y)** input jack.

3. Connect the probe ground clip to the chassis or common of the equipment under test. Connect the probe tip to the point of measurement.

4. If no waveforms appear, increase the sensitivity by turning the **CH 2 VOLTS/DIV** control clockwise to a position that gives 2 to 6 divisions vertical deflection.

5. The display on the CRT may be unsynchronized. Refer to the "Triggering" paragraphs in this section for procedures on setting triggering and sweep controls to obtain a stable display showing the desired number of waveforms.

DUAL TRACE DISPLAY

In observing simultaneous waveforms on channel 1 and 2, the waveforms are usually related in frequency, or one of the waveforms is synchronized to the other, although the basic frequencies are different. If the two waveforms have no phase or frequency relationship, there is seldom reason to observe both waveforms simultaneously. However, with **ALT** triggering, two waveforms not related in frequency or period can be simultaneously viewed.

1. Connect probes to both **CH 1 (X)** and **CH 2 (Y)** input jacks.

2. Connect the ground clips of the probes to the chassis or common of the equipment under test. Connect the tips of the probes to the two points in the circuit where waveforms are to be measured.

3. With the **ADD** function selected, the algebraic sum of CH 1 + CH 2 is displayed as a single trace. When the **PULL INV** button is also engaged, the algebraic difference of CH 1 - CH 2 is displayed.

4. To view both waveforms simultaneously, set the **VERT MODE** switch to **DUAL**.

5. When sweep times of 0.5 ms/div and faster are selected, the **ALT** display mode is automatically selected. When sweep times slower than 0.5 ms/div are selected, the **CHOP** display mode is automatically selected. It is possible to override the automatic selection by pulling out the **PULL CHOP** switch to select the **CHOP** display mode at all

sweep speeds or by pressing the **ALT TRIG** switch to select **ALT** display mode at all sweep speeds. However, do not engage **ALT** and **CHOP** display at the same time. Because selecting the **ALT** display mode also selects the **ALT TRIG** mode, selecting both **ALT** and **CHOP** simultaneously results in a display that cannot be synchronized since the chop signal itself becomes the trigger source. Use the **ALT** mode only, or select a trigger source of channel 1 or channel 2.

a. In the **ALT** mode, one sweep displays the channel 1 signal and the next sweep displays the channel 2 signal in an alternating sequence. Alternate sweep is normally used for viewing high-frequency or high-speed waveforms at sweep times of 1 ms/div and faster, but may be selected at any sweep time.

b. In the **CHOP** mode, the sweep is chopped at an approximate 250 kHz rate and switched between channel 1 and channel 2. Chop sweep is normally used for low-frequency or low-speed waveforms at sweep times of 1 ms/div and slower. If chop sweep is used at sweep times of 0.2 ms/div and faster, the chop rate becomes a significant portion of the sweep and may become visible in the displayed waveform. However, you may select chop sweep at any sweep time for special applications. For example, the only way to observe simultaneous events on a dual-trace scope at any sweep rate is with chop sweep.

6. Adjust the **CH 1** and **CH 2 POS** controls to place the channel 1 trace above the channel 2 trace.

7. Set the **CH 1** and **CH 2 VOLTS/DIV** controls to a position that gives 2 to 3 divisions of vertical deflection for each trace. If the display on the screen is unsynchronized, refer to the "Triggering" paragraphs in this section of the manual for procedures for setting triggering and sweep time controls to obtain a stable display showing the desired number of waveforms.

TRIGGERING

The Model 1541A Oscilloscope provides versatility in sync triggering for ability to obtain a stable, jitter-free display in single-trace, or dual-trace operation. The proper settings depend upon the type of waveforms being observed and the type of measurement desired. An explanation of the various controls which affect synchronization is given to help you select the proper setting over a wide range of conditions.

SWEEP MODE Switches

1. The **NORM** switch provides normal triggered sweep operation. The sweep remains at rest until the selected trigger source signal crosses the threshold level set by the **TRIG LEVEL** control. The trigger causes one sweep to be generated, after which the sweep again remains at rest until triggered. In the **NORM** position, there will be no trace unless an adequate trigger signal is present. In the **ALT** mode of dual trace operation with **NORM** sweep selected, there will be no trace unless both channel 1 and channel 2 signals are adequate for triggering. Typically, signals that produce even 1/2 division of vertical deflection are adequate for normal triggered sweep operation.

2. When the **AUTO** switch is engaged, automatic sweep operation is selected. In automatic sweep operation, the sweep generator free runs to generate a sweep without a trigger signal. However, it automatically switches to triggered sweep operation if an acceptable trigger source signal is present. The **AUTO** position is handy when first setting up the scope to observe a waveform; it provides sweep for waveform observation until other controls can be properly set. Once the controls are set, operation is often switched back to the **NORM** triggering

mode, since it is more sensitive. Automatic sweep must be used for dc measurements and signals of such low amplitude that they will not trigger the sweep.

NOTE

In the **X-Y** mode, the sweep generator and triggering circuits are disconnected and have no effect.

TRIGger SOURCE Switch

The **TRIG SOURCE** switch **CH 1**, **CH 2**, etc.) selects the signal to be used as the sync trigger. In the single trace display mode (**VERT MODE** set to either **CH 1** or **CH 2**), the channel selected for display is automatically selected as the trigger source unless the **TRIG SOURCE** switch is set to the **LINE** or **EXT** position.

1. If the **TRIG SOURCE** switch is set to **CH 1** (or **CH 2**) the channel 1 (or channel 2) signal becomes the trigger source when **DUAL** or **ADD VERT MODE** is selected. **CH 1**, or **CH 2** is often used as the trigger source for phase or timing comparison measurements.

2. If the **TRIG SOURCE** switch is set to the **LINE** position, triggering is derived from the input line voltage (50/60 Hz). This is useful for measurements that are related to line frequency.

3. If the **TRIG SOURCE** switch is set to the **EXT** position, the signal applied to the **EXT TRIG** jack becomes the trigger source. This signal must have a timing relationship to the displayed waveform(s) for a synchronized display.

ALT TRIG Switch

The **ALT TRIG** switch is used to select alternate triggering and alternate display when the **DUAL**-trace **VERT MODE** is selected (the switch has no effect in the **CH 1**, **CH 2**, or **ADD** modes). In the alternate triggering mode (when dual-trace operation is selected), the trigger source alternates between channel 1 and channel 2 with each sweep. This is convenient for checking amplitudes, waveshape, or waveform period measurements, and even permits simultaneous observation of two waveforms which are not related in frequency or period. However, this setting is not suitable for phase or timing comparison measurements. For such measurements, both traces must be triggered by the same sync signal.

When the **PULL CHOP** and the **ALT TRIG** switches are both engaged during dual-trace operation, synchronization of the display is not possible because the chopping signal becomes the trigger. Use the **ALT** mode by itself, or select **CH 1** or **CH 2** as the trigger source.

TRIG LEVEL and SLOPE Controls
(Refer to Fig. 4)

A sweep trigger is developed when the trigger source signal crosses a preset threshold level. Rotation of the **TRIG LEVEL** control varies the threshold level. In the + direction, the triggering threshold shifts to a more positive value, and in the - direction, the triggering threshold shifts to a more negative value. When the control is centered, the threshold level is set at the approximate average of the signal used as the triggering source. Rotating the control fully counterclockwise past the click stop, selects the **FIX** trigger mode. In the **FIX** mode, the trigger point is automatically set at the center of the waveform. Proper adjustment of this control usually synchronizes the display.

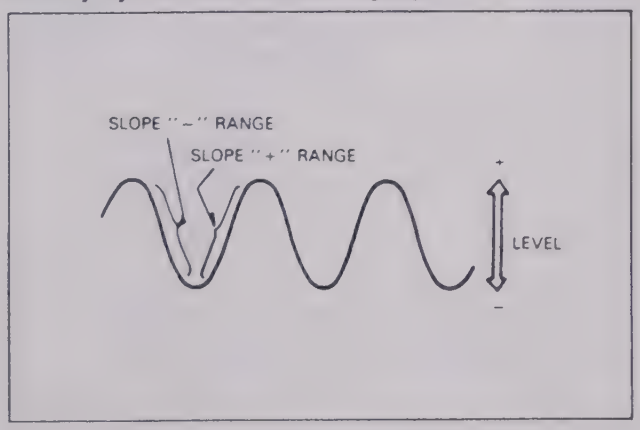

Fig. 4. Function of Slope and Level Controls.

The **TRIG LEVEL** control adjusts the start of the sweep to almost any desired point on a waveform. On sine wave signals, the phase at which sweep begins is variable. Note that if the **TRIG LEVEL** control is rotated toward its extreme + or - setting, no sweep will be developed in the **NORM** trigger mode because the

triggering threshold exceeds the peak amplitude of the sync signal.

When the **TRIG SLOPE** control is set to the (+) position (up), the sweep is developed from the trigger source waveform as it crosses the threshold level in a positive-going direction. When the **TRIG SLOPE** control is set to the (-) position (down), a sweep trigger is developed from the trigger source waveform as it crosses the threshold level in a negative-going direction.

COUPLING Switch

1. Use the **AC** position for viewing most types of waveforms. The trigger signal is capacitively coupled and may be used for all signals from 10 Hz to 40 MHz.

2. Use the **LF** position to eliminate high frequency components for stable triggering of low frequency signals.

3. The **TV** position is primarily for viewing composite video waveforms. A sync separator circuit separates sync pulses from video. Vertical sync pulses are selected as trigger when sweep speeds of 0.1 ms/div and slower are selected (**TV V**) and horizontal sync pulses are selected as trigger when sweep speeds of 50 µs/div and faster are selected (**TV H**). The **SLOPE** switch should be set according to the type of video signal (i.e., if the video signal has negative sync pulses, the **SLOPE** switch should be set to the (-) position. Additional procedures for observing video waveforms are given later in this section of the manual.

4. The **DC** position should be used when it is desirable to include the triggering effects of the dc component.

TIME/DIV Control

Set the **TIME/DIV** control to display the desired number of cycles of the waveform. If there are too many cycles displayed for good resolution, switch to a faster sweep speed. If only a line is displayed, try a slower sweep speed. When the sweep speed is faster than the waveform being observed, only part of it will be displayed, which may appear as a straight line for a square wave or pulse waveform.

HOLDOFF Control
(Refer to Fig. 5)

A "holdoff" period occurs immediately after the completion of each sweep, and is a period during which triggering of the next sweep is inhibited. The normal holdoff period varies with the sweep rate, but is adequate to assure complete retrace and stablization before the next sweep trigger is permitted. The **HOLDOFF** control allows this period to be extended by a variable amount if desired.

This control is usually set to the **NORM** position (fully counterclockwise) because no additional holdoff period is necessary. The **HOLDOFF** control is useful when a complex series of pulses appear periodically, such as in Fig. 5A. Improper sync may produce a double image as in Fig. 5B. Such a display could be synchronized with the **SWEEP/VAR** control, but this is impractical because time measurements are then uncalibrated. An alternate method of synchronizing the display is with the **HOLDOFF** control. The sweep speed remains the same, but the triggering of the next sweep is "held off" by the duration selected by the **HOLDOFF** control. Turn the **HOLDOFF** control clockwise from the **NORM** position until the sweep starts at the same point of the waveform each time. Maximum setting (turned fully clockwise) is 10 times greater than at the **NORM** setting.

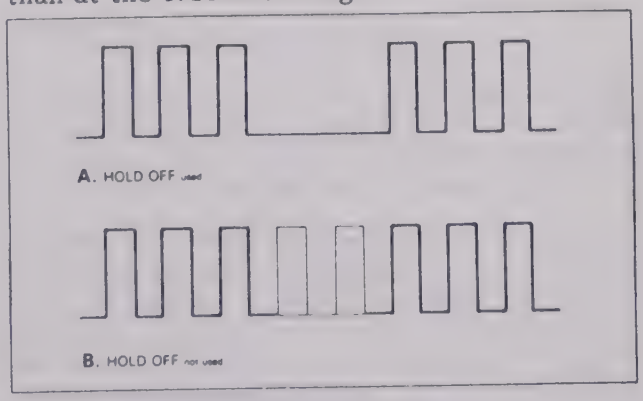

Fig. 5. Use of HOLDOFF control.

SINGLE SWEEP

This mode of display is useful for looking at non-synchronous or one time events.

1. Select either the **AUTO** or **NORM SWEEP MODE.** Apply a signal of approx-

imately the same amplitude and frequency as the signal that is to be observed as the trigger signal and set the trigger level.

2. Press and release the **SINGLE SWEEP MODE** switch (it will return to the disengaged position), make sure that the **READY** LED lights to indicate the reset condition. This LED goes out when the sweep period is completed.

3. The scope is now ready to operate in the **SINGLE** sweep mode of operation. Input of the trigger signal results in one and only one sweep.

NOTE

For dual-trace operation simultaneous observation is not possible using the **ALT** mode. Set the unit to the **CHOP** mode in this case.

X-Y OPERATION

X-Y operation permits the oscilloscope to perform many measurements not possible with conventional sweep operation. The CRT display becomes an electronic graph of two instantaneous voltages. The display may be a direct comparison of the two voltages such as a vectorscope display of video color bar patterns. However, the **X-Y** mode can be used to graph almost any dynamic characteristic if a transducer is used to change the characteristic (frequency, temperature, velocity, etc.) into a voltage. One common application is frequency response measurements, where the Y axis corresponds to signal amplitude and the X axis corresponds to frequency.

1. Set the **TRIG SOURCE** switch to the **CH 1/X-Y** position, the **VERT MODE** switch to the **CH 2/X-Y** position, and the **TIME/DIV** control to the **X-Y** position (fully counterclockwise). In this mode, channel 1 becomes the X axis input and channel 2 becomes the Y axis input.

2. The X and Y positions are now adjusted using the horizontal ◄► **POS** and **CH 2** ▲▼ **POS** controls respectively.

3. Adjust the amount of vertical (Y axis) deflection with the **CH 2 VOLTS/DIV** and **VAR** controls.

4. Adjust the amount of horizontal (X axis) deflection with the **CH 1 VOLTS/DIV** and **VAR** controls.

EXTERNAL HORIZONTAL OPERATION

In the **EXT** Horizontal operating mode, an external signal can be connected to the **EXT TRIG** input to control the oscilloscope sweep.

1. Set the **TRIG SOURCE** switch to the **EXT** position, the **VERT MODE** switch to the desired position (the **EXT** Horizontal mode can be used in single-trace, dual-trace, or add mode), and the **TIME/DIV** control to the **X-Y** position (fully counterclockwise). In this mode, the **EXT TRIG** input becomes the sweep signal.

2. The X and Y positions are now adjusted using the horizontal ◄► **POS** and ▲▼ **POS** controls respectively.

3. Adjust the amount of vertical (Y axis) deflection with the appropriate **VOLTS/DIV** and **VAR** controls (**CH 1** for **CH 1 VERT MODE**, **CH 2** for **CH 2 VERT MODE**, or both **CH 1** and **CH 2** for **DUAL VERT MODE**).

4. The amount of horizontal (X axis) deflection is controlled by the amplitude of the signal applied to the **EXT TRIG** jack.

VIDEO SIGNAL OBSERVATION

Setting the **TRIG COUPLING** switch to the **TV** position permits selection of vertical or horizontal sync pulses for sweep triggering when viewing composite video waveforms.

The **TV V** mode is automatically selected at sweep rates of 0.1 ms/div and slower. Vertical sync pulses are selected as trigger to permit viewing of vertical fields and frames of video. A sweep time of 2 ms/div is appropriate for viewing fields of video and 5 ms/div for complete frames (two interlaced fields) of video.

The **TV H** mode is automatically selected at sweep rates of 50 µs/div and slower. Horizontal sync pulses are selected as trigger to permit viewing of horizontal lines of video. A sweep time of about 10 µs/div is appropriate

for displaying lines of video. The **SWEEP/VAR** control can be set to display the exact number of waveforms desired.

At most points of measurement, a composite video signal is of the (-) polarity, that is, the sync pulses are negative and the video is positive. In this case, use **(-) SLOPE.** If the waveform is taken at a circuit point where the video waveform is inverted, the sync pulses are positive and the video is negative. In this case, use **(+) SLOPE.**

DC VOLTAGE MEASUREMENTS
(Refer to Fig. 6)

The following technique may be used to measure the instantaneous dc level at any portion of a waveform, or to measure a dc voltage where no waveform is present.

1. Connect the signal to be measured to the input jack and set the **VERT MODE** switch to the channel to be used. Set the **VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The **SWEEP/VAR** and volts/div **VAR** controls must be set to **CAL.**

2. Press the **AUTO SWEEP MODE** switch and set the **AC-GND-DC** switch to **GND**, which establishes a trace at the zero volt reference. Using the ▲▼ **POS** control, adjust the trace to the desired reference level position, making sure not to disturb this setting once made.

3. Set the **AC-GND-DC** switch to **DC** to observe the waveform, including its dc component. If an inappropriate reference level position was selected in step 2 or an inappropriate **VOLTS/DIV** setting was made, the waveform may not be visible at this point (deflected completely off the screen). This is especially true when the dc component is large with respect to the waveform amplitude. If so, reset the **VOLTS/DIV** control and repeat steps 2 and 3 until the waveform and the zero reference are both on the screen.

4. Use the ◄► **POS** control to bring the portion of the waveform to be measured to the center vertical graduation line of the graticule scale.

5. Measure the vertical distance from the zero reference level to the point to be measured (at least 3 divisions desirable for best accuracy). The reference level can be rechecked by momentarily returning the **AC-GND-DC** switch to **GND.**

6. Multiply the distance measured above by the **VOLTS/DIV** setting and the probe attenuation ratio as well. Voltages above the reference level are positive and voltages below the reference level are negative.

The measurement is summarized by the following equation:

DC level = Vert div x **VOLTS/DIV** x Probe

For the example shown in Fig. 6, the point being measured is 3.8 divisions from the reference level (ground potential). If the **VOLTS/DIV** control is set to 0.2 V and a 10:1 probe is used, the dc voltage level is calculated as follows:

DC level = 3.8 (div) x 0.2 (V/div) x 10

= 7.6 V

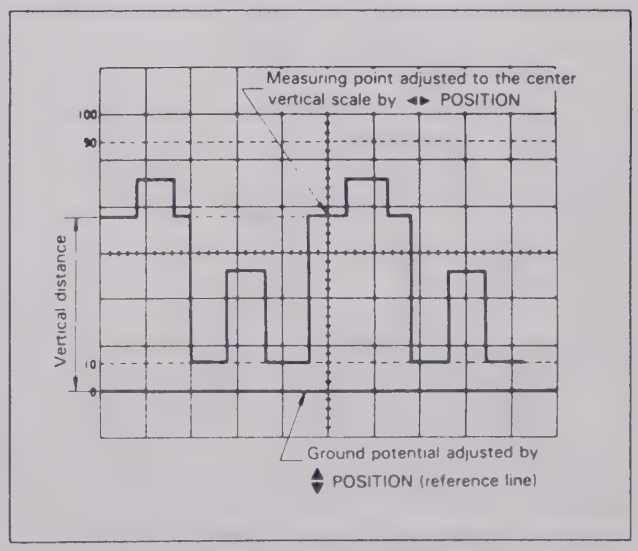

Fig. 6. DC Voltage Measurement.

MEASUREMENTS OF VOLTAGE BETWEEN TWO POINTS ON A WAVEFORM
(Refer to Fig. 7)

This procedure may be used to measure peak-to-peak voltages, or for measuring the

voltage difference between any two points on a waveform.

1. Connect the signal to be measured to the input connector, set the **VERT MODE** switch to the channel to be used, and set the **AC-GND-DC** switch to **AC.** Set the **VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The volts/div **VAR** control must be set to **CAL.**

2. Using the ↕ **POS** control, adjust the waveform position such that one of the two points falls on a major horizontal graduation line.

3. Using the ◄► **POS** control, adjust the second point to coincide with the center vertical graduation line.

4. Measure the vertical distance between the two points (at least 3 divisions desirable for best accuracy). Multiply the number of divisions by the setting of the **VOLTS/DIV** control. If a probe is used, further multiply this by the probe attenuation ratio.

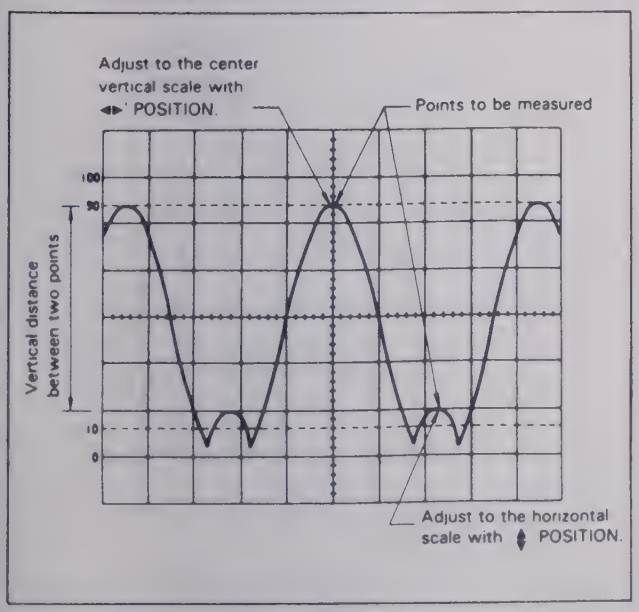

Fig. 7. Voltage Measurement.

The measurement is summarized by the following equation:

Voltage = Vert div x **VOLTS/DIV** x probe

For the example shown in Fig. 7, the two points are separated by 4.4 divisions vertically. If the **VOLTS/DIV** setting is 20 mV and a 10:1 probe is used, the voltage is calculated as follows:

Voltage = 4.4 (div) x 20 (mV/div) x 10

= 880 mV

ADD MODE APPLICATIONS

Differential Measurements
(Refer to Figs. 8 and 9)

The **ADD** mode can be conveniently used to measure a signal with a reference point other than earth ground. For example, if you wanted to measure the signal present across R2 in Fig. 8, you would use the following technique:

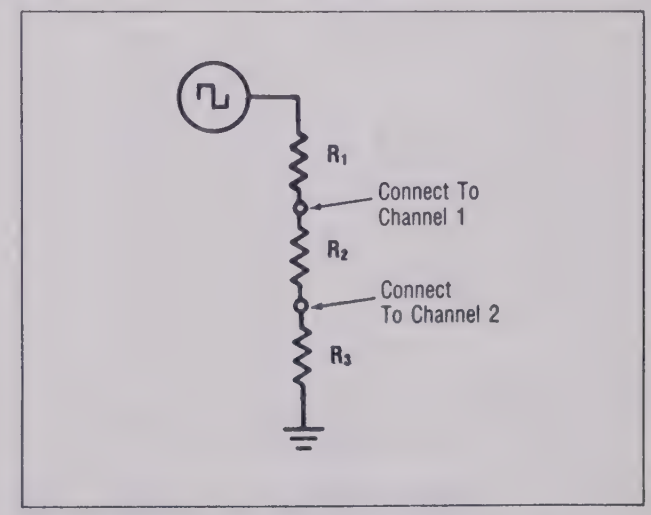

Fig. 8. Voltage Measurement with Reference Other than Earth Ground.

1. Connect channel 2 to the desired reference point and connect channel 1 to the desired point of measurement.

2. Select the subtract mode of operation by setting the **VERT MODE** switch to the **ADD** position and pulling out the **PULL/INV** switch.

3. Adjust the **CH 1** and **CH 2 VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The **VAR** controls must both be set

to **CAL** to make voltage measurements. Also, make sure that both attenuator controls are set to the same **VOLTS/DIV** settings.

4. Using the ch 1 or ch 2 ⇕ **POS**ition control, adjust the waveform position such that one of two points fall on a major horizontal graduation line.

5. Using the ◄► **POS**ition, adjust the second point to coincide with the center vertical graduation line.

6. Measure the vertical distance between the two points (at least 3 divisions desirable for best accuracy). Multiply the number of divisions by the setting of either **VOLTS/DIV** control. If probes are used, further multiply this by the attenuation ratio of either probe (make sure that both probes are of the same attenuation ratio).

The measurement is summarized by the following equation:

Voltage = Vert div x **VOLTS/DIV** x probe

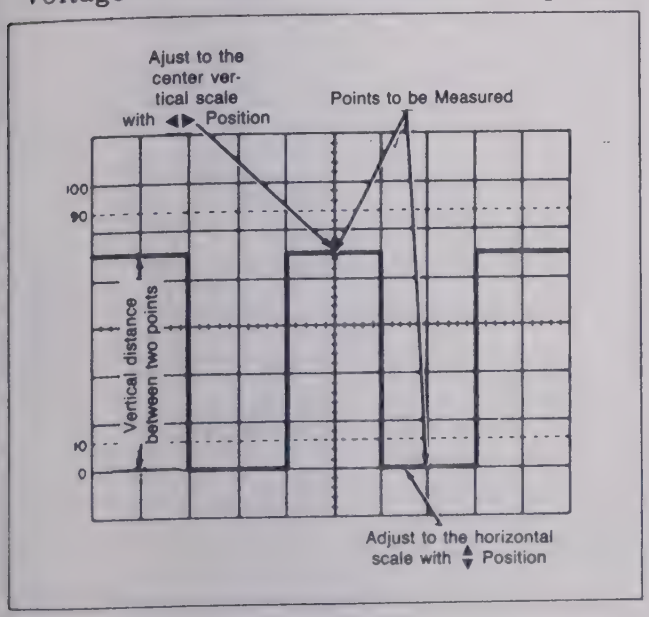

Fig. 9. Differential Voltage Measurement.

For the example shown in Fig. 9, the two points are separated by 4.5 divisions vertically. If the **VOLTS/DIV** setting is 0.1 V and a 10:1 probe is used, the voltage is calculated as follows:

Voltage = 4.5 (div) x 0.1 (V/div) x 10

= 4.5 V

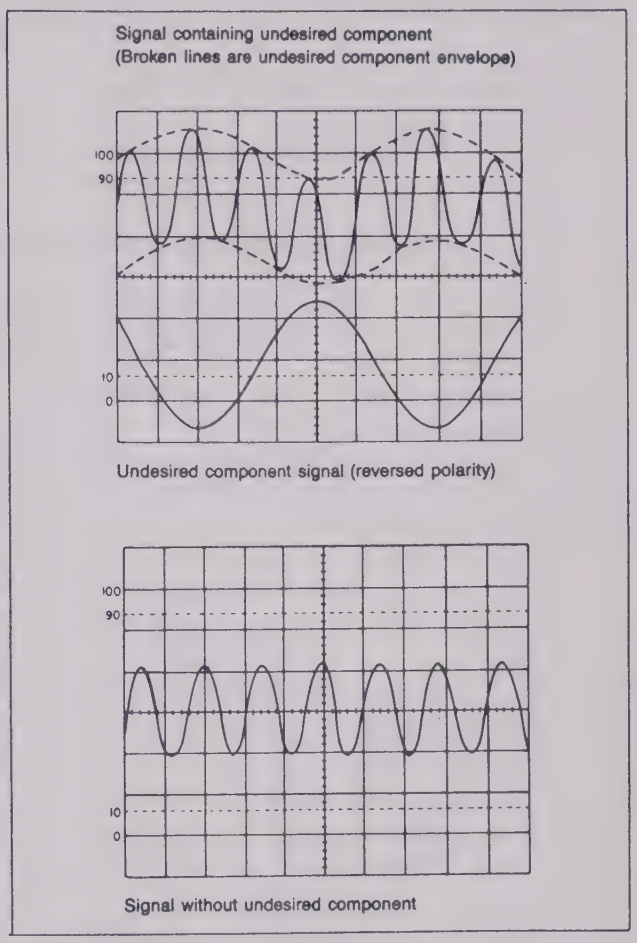

Fig. 10. Eliminating An Undesired Signal Component.

Elimination of an Undesired Signal Component
(Refer to Fig. 10)

Another application of the **ADD** mode is to cancel out the effect of an undesired signal component which is superimposed on the signal you wish to observe (for example, undesired 60 Hz hum superimposed on an rf signal).

1. Apply the signal containing an undesired component to the **CH 1 (X)** input jack and the undesired signal itself alone to the **CH 2 (Y)** input jack.

2. Select the **DUAL**-trace mode, pull out the **PULL CHOP** switch, and set the

voltage difference between any two points on a waveform.

1. Connect the signal to be measured to the input connector, set the **VERT MODE** switch to the channel to be used, and set the **AC-GND-DC** switch to **AC**. Set the **VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The volts/div **VAR** control must be set to **CAL**.

2. Using the ↕ **POS** control, adjust the waveform position such that one of the two points falls on a major horizontal graduation line.

3. Using the ◄► **POS** control, adjust the second point to coincide with the center vertical graduation line.

4. Measure the vertical distance between the two points (at least 3 divisions desirable for best accuracy). Multiply the number of divisions by the setting of the **VOLTS/DIV** control. If a probe is used, further multiply this by the probe attenuation ratio.

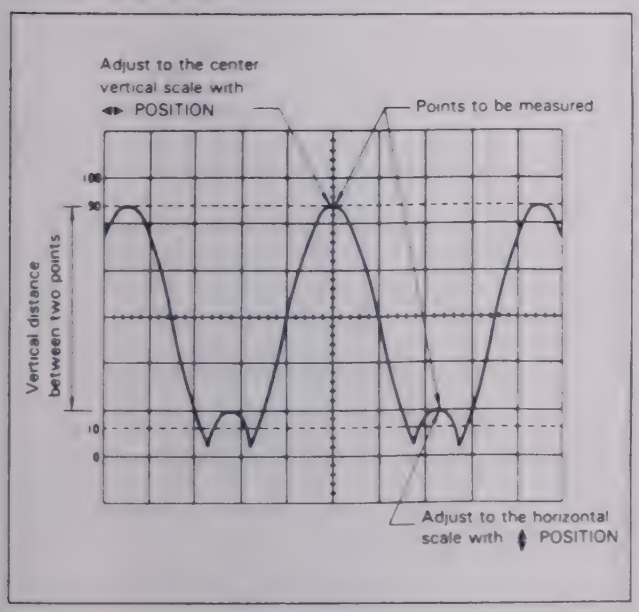

Fig. 7. Voltage Measurement.

The measurement is summarized by the following equation:

Voltage = Vert div x **VOLTS/DIV** x probe

For the example shown in Fig. 7, the two points are separated by 4.4 divisions vertically. If the **VOLTS/DIV** setting is 20 mV and a 10:1 probe is used, the voltage is calculated as follows:

Voltage = 4.4 (div) x 20 (mV/div) x 10

= 880 mV

ADD MODE APPLICATIONS

Differential Measurements
(Refer to Figs. 8 and 9)

The **ADD** mode can be conveniently used to measure a signal with a reference point other than earth ground. For example, if you wanted to measure the signal present across R2 in Fig. 8, you would use the following technique:

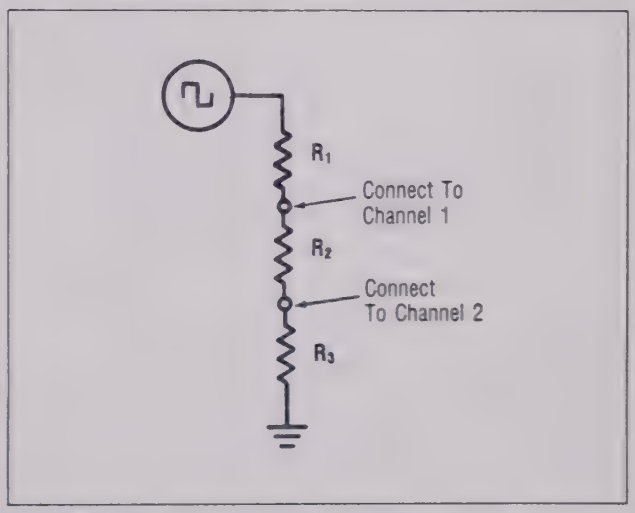

Fig. 8. Voltage Measurement with Reference Other than Earth Ground.

1. Connect channel 2 to the desired reference point and connect channel 1 to the desired point of measurement.

2. Select the subtract mode of operation by setting the **VERT MODE** switch to the **ADD** position and pulling out the **PULL/INV** switch.

3. Adjust the **CH 1** and **CH 2 VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The **VAR** controls must both be set

TRIG SOURCE switch to **CH 2.** Adjust the controls to display two signals, such as shown in Fig. 10. Verify that the channel 2 trace represents the unwanted signal in reverse polarity. The polarity may be reversed by engaging the **PULL INV** switch.

3. Now set the **VERT MODE** switch to **ADD** and push in the **PULL CHOP** control. Adjust the **CH 2 VOLTS/DIV** and **VAR** controls so that the undesired signal component is cancelled as much as possible. The remaining signal should be the signal you wish to observe alone, free of the unwanted signal.

Push-Pull Amplifier Measurements

The oscilloscope's **ADD** mode can also be conveniently used to make signal measurements and check for proper balance at the outputs of push-pull amplifiers.

1. Connect one channel to one amplifier output and the other channel to the other amplifier output.

2. Select the subtract mode of operation by setting the **VERT MODE** switch to the **ADD** position and pulling the **PULL INV** switch.

NOTE

Because the two outputs of a push-pull amplifier are out of phase they tend to subtract. It is necessary to invert the channel 2 input to cause the signals to add.

3. Adjust the **CH 1** and **CH 2 VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. The **VAR** controls must both be set to **CAL** to make voltage measurements. Also, make sure that both attenuator controls are set to the same **VOLTS/DIV** settings.

4. Make peak-to-peak signal measurements by performing steps 4 through 6 of "Differential Voltage Measurements".

5. To check amplifier balance, press the **PULL INV** switch and observe the display. If the amplifier is perfectly balanced, the two outputs should fully cancel each other. The resulting displayed waveform should be a flat trace. Any displayed signal equals the imbalance.

TIME MEASUREMENTS
(Refer to Fig. 11)

This is the procedure for making time (period) measurements between two points on a waveform. The two points may be the beginning and ending of one complete cycle if desired.

1. Connect the signal to be measured to the input connector and set the **VERT MODE** switch to the channel to be used. Set the **VOLTS/DIV** and **TIME/DIV** controls to obtain a normal display of the waveform to be measured. Be sure the **SWEEP/VAR** control is set to **CAL.**

2. Using the ▲▼ **POS** control, set one of the points to be used as a reference to coincide with the horizontal center line. Use the ◄► **POS** control to set this point at the intersection of any vertical graduation line.

3. Measure the horizontal distance between the two points (at least 4 divisions desirable for best accuracy). Multiply this by the setting of the **TIME/DIV** control to obtain the time between the two points. If **X10 MAG** is used, multiply this further by 1/10.

The measurement is summarized by the following equation:

Time = Hor div x **TIME/DIV**

(x 1/10 if **X10 MAG** is used)

For the example shown in Fig. 11, the horizontal distance between the two points is 5.4 divisions. If the **TIME/DIV** setting is 0.2 ms and **X10 MAG** is not used, the time period is calculated as follows:

Time = 5.4 (div) x 0.2 (ms/div)

= 1.08 ms

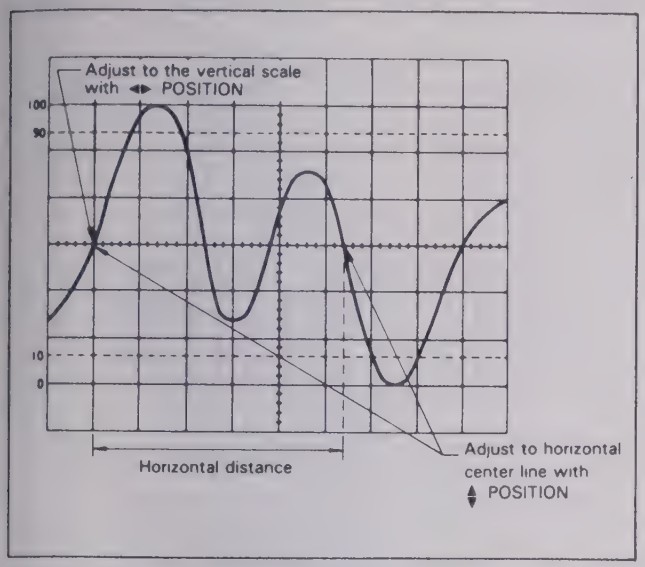

Fig. 11. Time Measurement.

FREQUENCY MEASUREMENTS

Method No. 1
(Refer to Fig. 12)

Frequency measurements are made by measuring the time period of one cycle of waveform and calculating the frequency, which equals the reciprocal of the time period.

1. Set up the oscilloscope to display one cycle of waveform (see Fig. 12).

2. Measure the time period of one cycle and calculate the frequency as follows:

$$\text{Freq} = \frac{1}{\text{Period}}$$

In the example shown in Fig. 12, a period of 40 µs is observed. Substituting this value into the above equation, the frequency is calculated as follows:

$$\text{Freq} = \frac{1}{40 \times 10^{-6}}$$

$$= 2.5 \times 10^{4}$$

$$= 25 \text{ kHz}$$

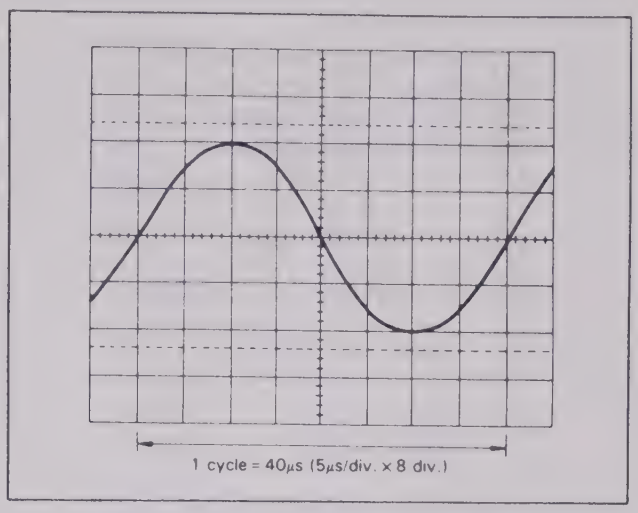

Fig. 12. Frequency Measurement.

Method No. 2
(Refer to Fig. 13)

While the previously described method relies upon direct period measurement of one cycle, the frequency may also be measured by counting the number of cycles present in a given time period.

1. Set up the oscilloscope to display several cycles of the waveform. The **SWEEP/VAR** control must be set to **CAL.**

2. Count the number of cycles of waveform between a chosen set of vertical graduation lines (see Fig. 13).

3. Multiply the number of horizontal divisions by the **TIME/DIV** setting to calculate the time span. Multiply the reciprocal of this value by the number of cycles present in the time span. If **X10 MAG** is used, multiply this further by 10. Note that errors will occur for displays having only a few cycles.

The measurement is summarized by the following equation:

$$\text{Freq} = \frac{\text{No of cycles (x 10 for X10 MAG)}}{\text{Hor div} \times \text{TIME/DIV}}$$

For the example shown in Fig. 13, there are 10 cycles within 7 divisions. If the **TIME/DIV** setting is 5 µs and **X10 MAG** is not used, the frequency is calculated as follows:

$$\text{Freq} = \frac{10\ (\text{cycles})}{7\ (\text{div})\ \times\ 5\ (\mu s)} = 285.7\ \text{kHz}$$

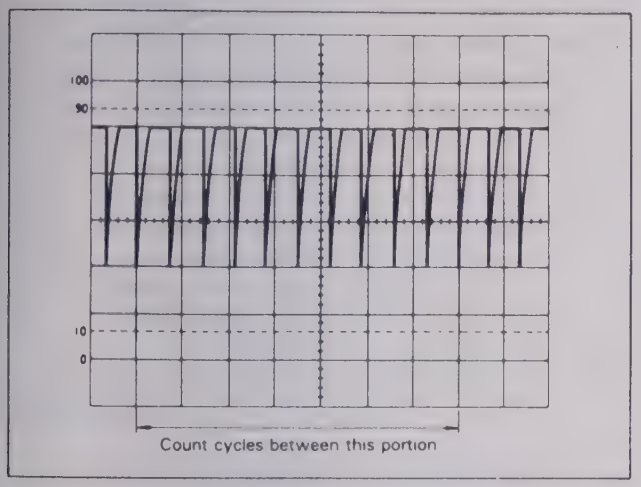

Fig. 13. Alternate Method of Frequency Measurement.

PULSE WIDTH MEASUREMENTS
(Refer to Fig. 14)

1. Apply the pulse signal to the input jack and set the **VERT MODE** switch to the channel to be used.

2. Use the **VOLTS/DIV** and volts/div **VAR** controls to adjust the display so the waveform is easily observed. Use the ↕ **POS** control to position the pulse over the center horizontal graduation line. Use the ↔ **POS** control to align the leading edge of the pulse with one of the vertical graduation lines.

3. Measure the distance between the leading edge and trailing edge of the pulse (along the center horizontal graduation line). Be sure that the **SWEEP/VAR** control is set to **CAL.** Multiply the number of horizontal divisions by the **TIME/DIV**, and if **X10 MAG** is used, further multiply this value by 1/10.

The measurement is summarized by the following equation:

Pulse Width = Hor div x **TIME/DIV**

(x 1/10 if **X10 MAG** is used)

For the example shown in Fig. 14, the pulse width at the center of the pulse is 4.6 divisions. If the **TIME/DIV** setting is 0.2 ms and **X10 MAG** is used, the pulse width is calculated as follows:

Pulse Width =

4.6 (div) x 0.2 (ms/div) x 1/10

= .092 ms or 92 μs

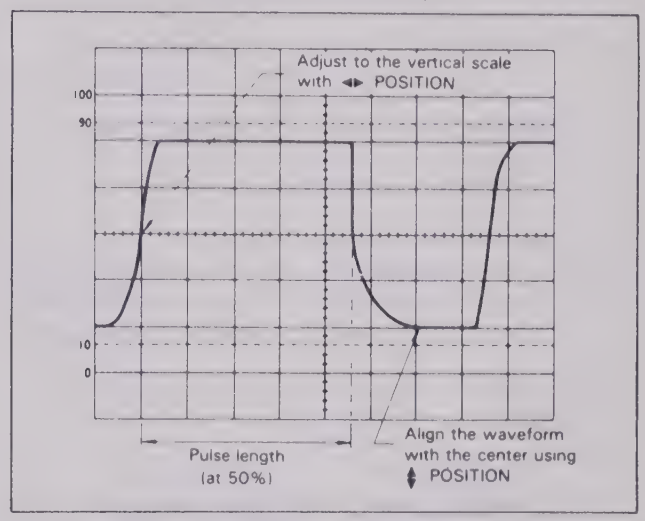

Fig. 14. Pulse Width Measurement.

PULSE RISE TIME AND FALL TIME MEASUREMENTS

Method No. 1:
(Refer to Fig. 15)

For rise time and fall time measurements, the 10% and 90% amplitude points are used as starting and ending reference points.

1. Apply a signal to the input jack and set the **VERT MODE** switch to the channel to be used. Use the **VOLTS/DIV** and volts/div **VAR** controls to adjust the waveform peak to peak height to six divisions.

2. Using the ↕ **POS** control, adjust the display so that the waveform is centered vertically on the display. Set the **TIME/DIV** control to a setting as fast as possible while still being able to observe the 10% and 90% points. Set the **SWEEP/VAR** control to the **CAL** position.

3. Use the ◄► **POS** control to adjust the 10% point to coincide with a vertical graduation line and measure the horizontal distance in divisions between the 10% and 90% points on the waveform. Multiply this by the **TIME/DIV** setting and also by 1/10 if the **X10 MAG** mode was used.

NOTE

Be sure that the correct 10% and 90% lines are used. For such measurements the 0, 10, 90, and 100% points are marked on the CRT screen.

The measurement is summarized by the following equation:

Rise Time = Hor div x **TIME/DIV**

(x 1/10 if X10 MAG is used)

For the example shown in Fig. 15, the horizontal distance is 4.0 divisions. The **TIME/DIV** setting is 2 µs. The rise time is calculated as follows:

Rise Time = 4.0 (div) x 2 (µs/div) = 8 µs

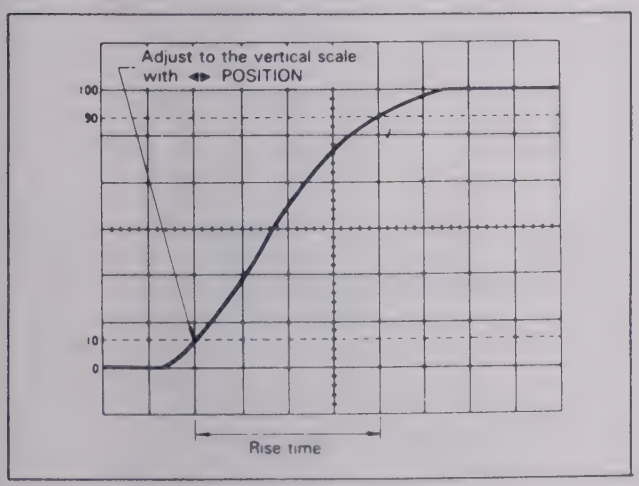

Fig. 15. Rise Time and Fall Time Measurement.

Method No. 2:
(Refer to Fig. 16)

The following step can be substituted for step 3 in method No. 1:

Use the ◄► **POS** control to set the 10% point to coincide with the center vertical graduation line and measure the horizontal distance to the point of the intersection of the waveform with the center horizontal line. Let this distance be D_1. Next, adjust the waveform position so that the 90% point coincides with the vertical centerline and measure the distance from that line to the intersection of the waveform with the horizontal centerline. Let this distance be D_2. The total horizontal distance is D_1 plus D_2.

The following equation summarizes the measurement:

Rise Time = $(D_1 + D_2)$ x **TIME/DIV**

(x 1/10 if **X10 MAG** is used)

For the example shown in Fig. 16, D_1 is 1.8 divisions and D_2 is 2.2 divisions. If the **TIME/DIV** setting is 2 µs, the rise time is calculated as follows:

Rise Time = (1.8 + 2.2) x 2 (µs/div) = 8 µs

NOTE

See APPENDIX I for important rise and fall time considerations.

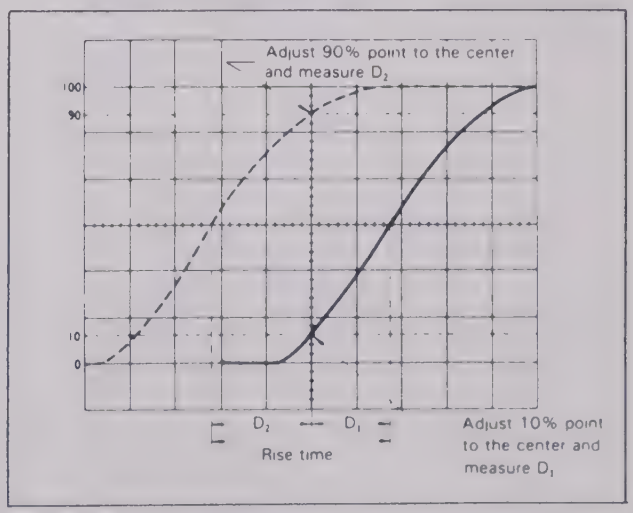

Fig. 16. Rise Time and Fall Time Measurement.

TIME DIFFERENCE MEASUREMENTS
(Refer to Fig. 17)

This procedure is useful in measurement of time difference between signals that are synchronized to one another but skewed in time.

1. Apply the two signals to the **CH 1 (X)** and **CH 2 (Y)** input jacks and select the dual-trace display mode.

2. Select the faster of the two signals as the **TRIG SOURCE** and use the **VOLTS/DIV** and **TIME/DIV** controls to obtain an easily observed display.

3. Use the ↕ **POS** controls to superimpose both waveforms to intersect the center horizontal graduation line as shown in Fig. 17. Use the ◄► **POS** control to set the reference signal coincident with one of the vertical graduation lines.

4. Measure the horizontal distance between the two signals and multiply this distance (in divisions) by the **TIME/DIV** setting. If **X10 MAG** is used, multiply this again by 1/10.

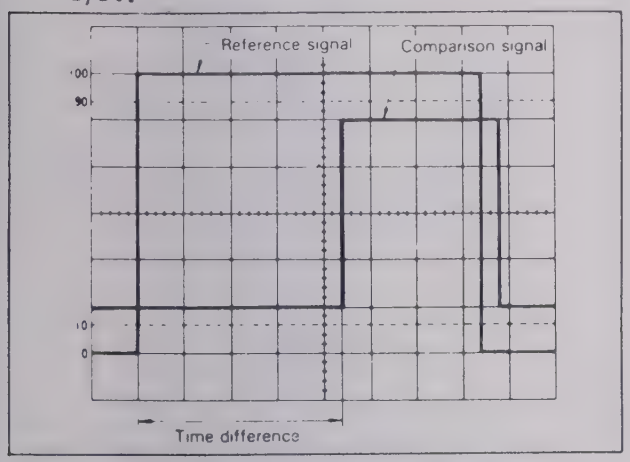

Fig. 17. Time Difference Measurement.

The measurement is summarized by the following equation:

Time = Hor div x **TIME/DIV**

(x 1/10 if **X10 MAG** is used)

For the example shown in Fig. 17, the horizontal distance measured is 4.4 divisions. If the **TIME/DIV** is 0.2 ms and **X10 MAG** is not used, the time difference is calculated as follows:

Time = 4.4 (div) x 0.2 (ms/div)

= 0.88 ms or 880 µs

PHASE DIFFERENCE MEASUREMENTS

Method No. 1
(Refer to Fig. 18)

This procedure is useful in measuring the phase difference of signals of the same frequency.

1. Apply the two signals to the **CH 1 (X)** and **CH 2 (Y)** input jacks, selecting the dual-trace display mode.

2. Set the **TRIG SOURCE** switch to the signal which is leading in phase and use the **VOLTS/DIV** controls to adjust the two waveforms so they are equal in amplitude.

3. Use the ↕ **POS** controls to position the waveforms in the vertical center of the screen. Use the **TIME/DIV** and **SWEEP/VAR** controls to adjust the display so one cycle of the reference signal occupies 8 divisions horizontally (see Fig. 18). The trigger **LEVEL** and ◄► **POS** controls are also useful in achieving this display. The display should be as shown in Fig. 18, where one division now represents 45° in phase.

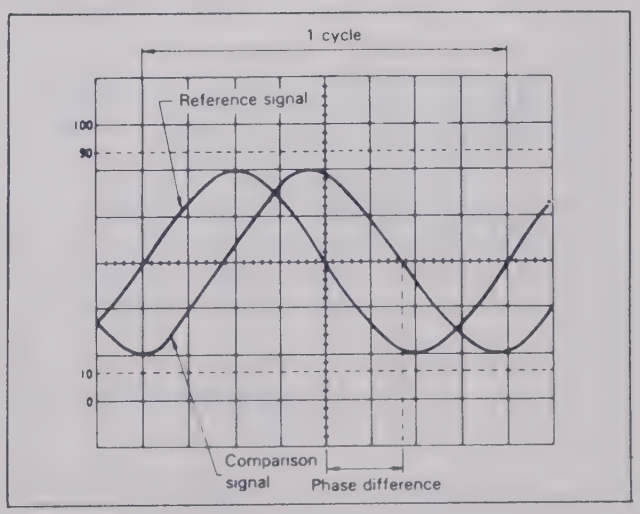

Fig. 18. Phase Difference Measurement.

4. Measure the horizontal distance between corresponding points on the two waveforms. Multiply the distance (in divisions) times 45° per division to obtain the phase difference.

The measurement is summarized by the following equation:

$$\text{Phase difference} = \text{Hor div} \times 45^{\circ}/\text{div}$$

For the example shown in Fig. 18, the horizontal distance is 1.7 divisions. Thus, the phase difference is calculated as follows:

$$\text{Phase difference} = 1.7 \times 45^{\circ}/\text{div} = 76.5^{\circ}$$

Method No. 2
(Refer to Fig. 19)

The above procedure allows 45° per division, which may not give the desired accuracy for small phase differences.

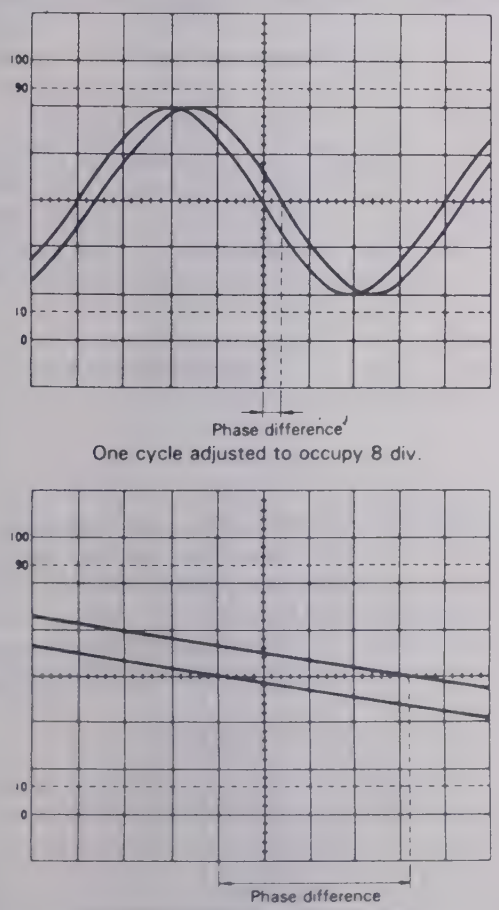

Fig. 19. Measuring Small Phase Difference.

If greater accuracy is required, the **TIME/DIV** setting may be changed to expand the display as shown in Fig. 19, but the **SWEEP/VAR** setting must not be touched. If necessary, the **TRIG LEVEL** control may be readjusted. For this type of operation, the relationship of one division to 45° no longer holds. Instead the following equation must be used:

$$\text{Phase diff} = \text{Hor div} \times 45^{\circ}/\text{div} \times \frac{A}{B}$$

Where:
A = New **TIME/DIV** setting.
B = Original **TIME/DIV** setting.

A simpler method of obtaining more accuracy quickly is to simply use **X10 MAG** for a scale factor of 4.5°/division.

RELATIVE MEASUREMENTS

If the amplitude and period of some reference signal are known, an unknown signal may be measured for amplitude and period without the volts/div and **SWEEP/VAR** controls set to **CAL.** The measurement is made in units relative to the reference signal.

Relative Voltage Measurements
(Refer to Fig. 20)

1. Apply the reference signal to the input jack and adjust the display for a normal waveform display. Adjust the **VOLTS/DIV**, volts/div **VAR**, and **SWEEP/VAR** controls so that the amplitude of the reference signal occupies a fixed number of divisions. After adjusting, be sure not to disturb the setting of the volts/div **VAR** control.

2. Calculate the vertical calibration coefficient as follows:

$$\text{vertical coefficient} = \frac{C}{D \times E}$$

Where:
C = Amplitude of reference signal (in volts).
D = Amplitude of reference signal (in divisions).
E = **VOLTS/DIV** setting.

3. Remove the reference signal and apply the unknown signal to the input jack, using only the **VOLTS/DIV** control to adjust the amplitude for easy observation (do not disturb the volts/div **VAR** setting).

4. Measure the amplitude of the displayed waveform, in divisions. Multiply the number of divisions by the **VOLTS/DIV** setting and the vertical coefficient from above to find the value of the unknown voltage.

The measurement is summarized by the following equation:

Unknown Voltage = Vert div x **VOLTS/DIV**

x vert coefficient

For the example shown in Fig. 20, the **VAR** control is adjusted so the amplitude of the reference signal is 4 divisions. If the reference signal is 2.0 V p-p, and the **VOLTS/DIV** setting is 1 V, the vertical coefficient is 0.5; which was calculated as follows:

$$\text{vertical coefficient} = \frac{2\ (V)}{4\ (\text{div})\ \times\ 1\ (V/\text{div})}$$

$$= 0.5$$

For the example shown in Fig. 20, the amplitude of the unknown signal is 3 divisions, and the previously calculated vertical coefficient is 0.5. If the **VOLTS/DIV** setting is 5 V, the unknown signal is 7.5 V p-p; which was calculated as follows:

Unknown Voltage =

3 (div) x 5 (V/div) x 0.5 (vert coef)

= 7.5 V

NOTE

It is preferable that the reference voltage be the peak-to-peak value, as in the previous example. The measurement holds true for all waveforms if a p-p reference is used. It is also possible to use an rms value for the reference voltage. The unknown voltage value will also be in rms, but the measurement holds true only if both the reference and unknown signals are undistorted sine waves.

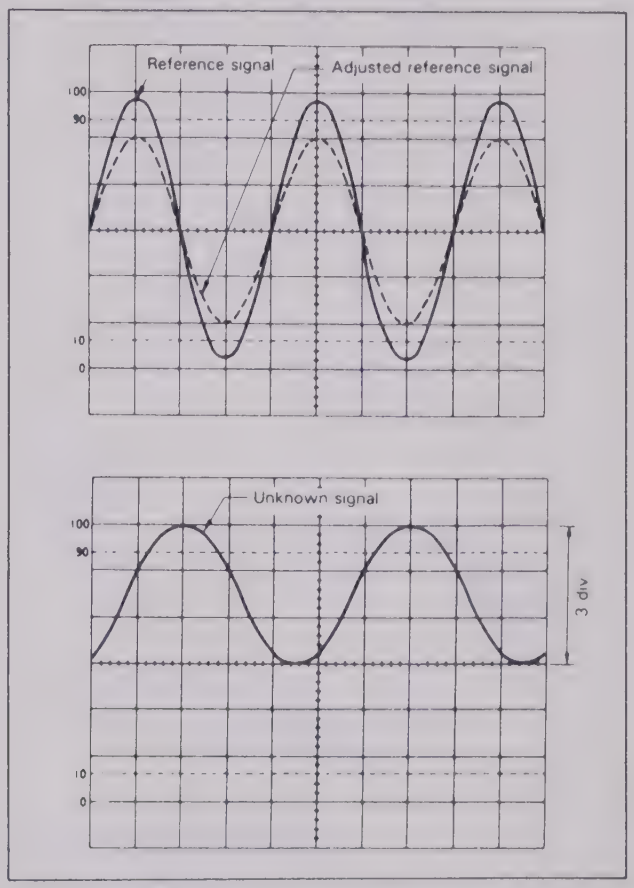

Fig. 20. Voltage Measurement, Relative Method.

Relative Period Measurements
(Refer to Fig. 21)

1. Apply the reference signal to the input jack and adjust the display for a normal waveform display. Using the **TIME/DIV** and **SWEEP/VAR** controls, adjust one cycle of the reference signal to occupy a fixed number of horizontal divisions. After this is done, be sure not to disturb the **SWEEP/VAR** control setting.

2. Calculate the sweep (horizontal) calibration coefficient using the following equation:

$$\text{Sweep coefficient} = \frac{F}{G \times H}$$

Where:

F = Period of reference signal (seconds).
G = Horizontal width of reference signal (divisions).
H = **TIME/DIV** setting.

3. Remove the reference signal and apply the unknown signal to the input jack, using only the **TIME/DIV** control to adjust the width of the display (do not disturb the **SWEEP/VAR** setting).

4. Measure the width of one cycle of the displayed waveform, in divisions. Multiply the number of divisions by the **TIME/DIV** setting and the sweep coefficient from above to find the period of the unknown waveform.

The measurement is summarized by the following equation:

Unknown Period = Horizontal divisions x

TIME/DIV x sweep coefficient

For the example in Fig. 21A, the **SWEEP/VAR** control is adjusted so the reference signal occupies 5 horizontal divisions. If the reference signal is 1.75 kHz, and the **TIME/DIV** control is 0.1 ms, the sweep coefficient is calculated as follows:

$$\text{sweep coefficient} = \frac{1.75\ \text{kHz}^{-1}}{5\ (\text{div}) \times 0.1\ (\text{ms/div})}$$

$$= 1.143$$

For the example in Fig. 21B, the width of the unknown signal is 7 divisions, and the previously calculated sweep coefficient is 1.143. If the **TIME/DIV** setting is 0.2 ms, the period is calculated as follows:

Unknown Period =

7 (div) x 0.2 (ms/div) x 1.143 (sweep coef)

= 1.6 ms

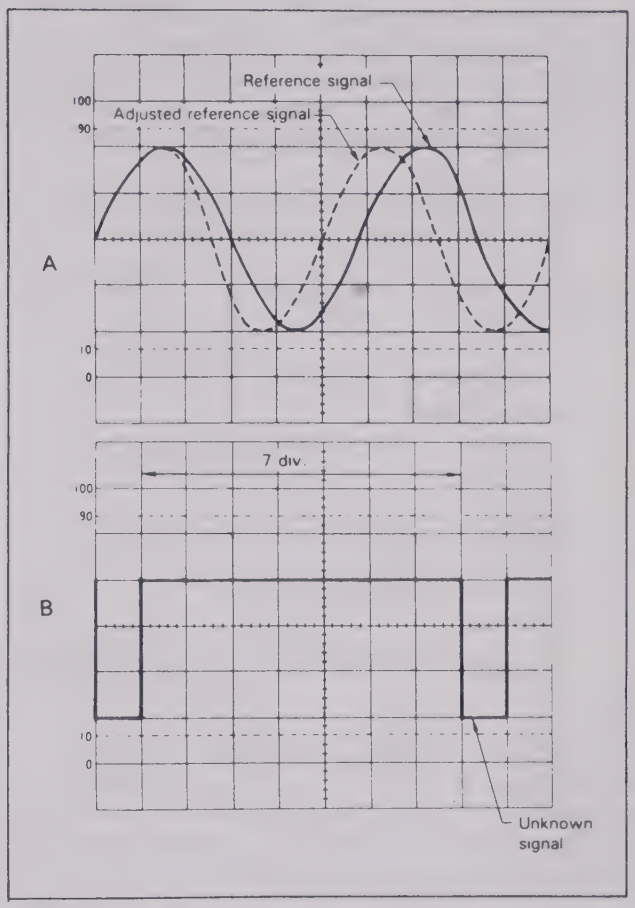

Fig. 21. Period Measurement, Relative Method.

X-Y MODE APPLICATIONS

Phase Measurements

(Refer to Fig. 22)

A dual-trace method of phase measurement was previously described. A second method of phase measurement requires calculations based on the Lissajous patterns obtained using X-Y operation. Distortion due to non-linear amplification can also be displayed.

A sine wave is applied to the audio circuit being tested. The same sine wave is also applied to the vertical input of the oscilloscope, and the output of the tested circuit is applied to the horizontal input of the oscilloscope. The amount of phase difference between the two signals can be calculated from the resulting waveform.

1. Using an audio generator with a pure sinusoidal signal, apply a sine wave test signal at the desired test frequency to the audio network being tested.

2. Set the signal generator output for the normal operating level of the circuit being tested. If desired, the circuit's output may first be observed on the oscilloscope with normal sweep operation. If the test circuit is overdriven, the sine wave display on the oscilloscope is clipped and the signal level must be reduced.

3. Connect channel 1 to the input and channel 2 to the output of the test circuit. Set channel 1 and 2 gain controls for exactly the same amplitude waveform on the display in normal sweep operation.

4. Select X-Y operation by setting the **TIME/DIV** control fully counterclockwise (**X-Y**), the **TRIG SOURCE** switch to the **CH 1/X-Y** position, and the **VERT MODE** switch to the **CH 2/X-Y** position.

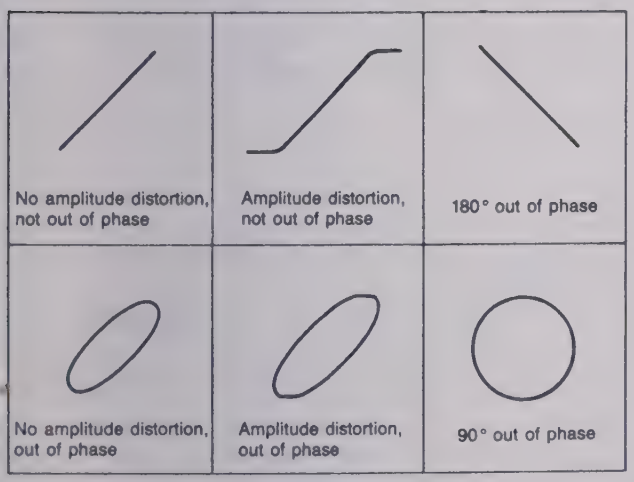

Fig. 22. Typical X-Y Phase Measurement Displays.

5. If necessary, repeat step 3, readjusting the channel 1 and 2 gain controls for a suitable viewing size. Some typical results are shown in Fig. 22.

If the two signals are in phase, the oscilloscope trace is a straight diagonal line. If the vertical and horizontal gain are properly adjusted, this line is at a 45° angle. A 90° phase shift produces a circular oscilloscope pattern. Phase shift of less (or more) than 90° produces an elliptical oscilloscope pattern. The amount of phase shift can be calculated from the oscilloscope trace as shown in Fig. 23.

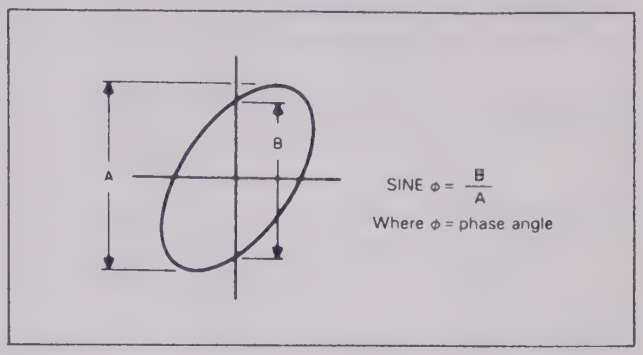

Fig. 23. Phase Measurement, X-Y Operation.

Frequency Response Measurements
(Refer to Fig. 24)

A sweep generator and the X-Y mode of this oscilloscope may be used to measure the audio or rf frequency response of an active or passive device up to 40 MHz, such as an amplifier, band pass filter, coupling network, etc.

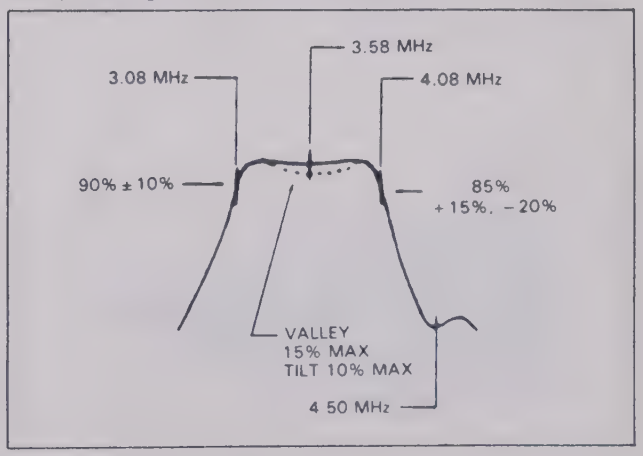

Fig. 24. Frequency Response Measurement.

1. Connect the audio or rf output of the sweep generator to the input of the circuit under test and the output of the test circuit to channel 1 (vertical axis) of the oscilloscope. A demodulator probe will give a "text book" frequency response display as shown in Fig. 24, but a stand-

ard probe can be used which will result in an envelope display.

2. Connect the sweep ramp voltage of the sweep generator to the channel 2 input of the oscilloscope.

3. Set the **TIME/DIV** control to the **X-Y** position (fully counterclockwise), the **TRIG SOURCE** switch to the **CH 1/X-Y** position, the **VERT MODE** switch to the **CH 2/X-Y** position, and adjust the channel 1 and 2 controls for a suitable viewing size.

EXTERNAL HORIZONTAL SWEEP APPLICATIONS

(Refer to Fig. 25 and 26)

The **EXT** Horizontal operating mode allows the Model 1541A oscilloscope to be used to view a frequency response sweep envelope. Unlike oscilloscopes which have no external sweep input, a frequency response sweep envelope can be synchronized, allowing for a synchronized, usable frequency response display. Typical frequency response envelopes can be viewed as follows (Refer to Fig. 25 for set-up):

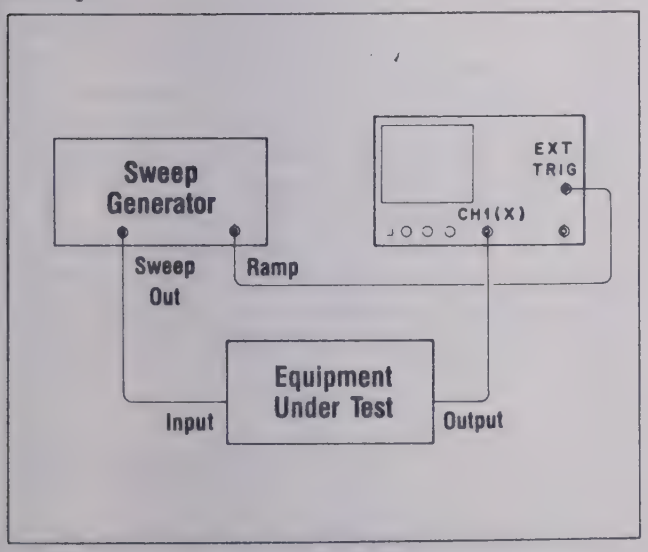

Fig. 25. Frequency Response Set-Up.

1. Set the **TIME/DIV** control on the oscilloscope to the **X-Y** position (fully counterclockwise), the **TRIG SOURCE** switch to the **EXT** position, and the **VERT MODE** switch to the **CH 1** position.

2. Connect a sweep/function generator to the input of the equipment to be tested.

3. Connect the output of the equipment under test to the **CH 1 (X)** input on the oscilloscope.

4. Connect the sweep ramp output of the sweep/function generator to the **EXT TRIG** input on the oscilloscope.

5. Set the sweep/function generator up for the fastest sweep possible (a faster sweep causes the oscilloscope display to "flicker" less) and set the desired start and stop sweep points.

6. Adjust the **CH 1 VOLTS/DIV** control to obtain about five or six vertical divisions of signal at it's highest amplitude.

7. The oscilloscope display should now show a frequency response envelope. The response in Fig. 26 is that of a circuit that has attenuation at lower frequencies.

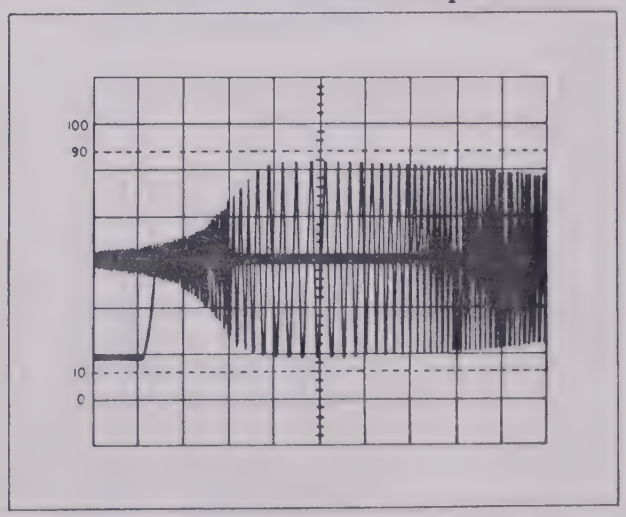

Fig. 26. Frequency Response Envelope.

WARNING

The following instructions are for use by qualified service personnel only. To avoid electrical shock, do not perform any servicing other than contained in the operating instructions unless you are qualified to do so.

High voltage up to 12,000 volts is present when covers are removed and the unit is operating. Remember that high voltage may be retained indefinitely on high voltage capacitors. Also remember that ac line voltage is present on line voltage input circuits any time the instrument is plugged into an ac outlet, even if turned off. Unplug the oscilloscope and discharge high voltage capacitors before performing service procedures.

FUSE REPLACEMENT

If the fuse blows, the pilot light will go out and the oscilloscope will not operate. The fuse should not normally open unless a problem has developed in the unit. Try to determine and correct the cause of the blown fuse, then replace only with the correct value fuse. For 100 V or 120 V operation, use a 0.5 A, 250 V, 3 AG, slow-blow fuse (Dynascan part number 190-251-3-102). For 220 V, 230 V, or 240 V operation, use a 0.3 A, 250 V, 3 AG, slow-blow fuse (Dynscan part number 190-004-9-001). The fuse is located on the rear panel (see Fig. 2).

CASE REMOVAL

To remove the case from the Model 1541A oscilloscope, perform the following steps:

1. Unplug the line cord.

2. Remove the nine screws that secure the top case to the chassis (three along each bottom edge of the top case and three at the back of the top case).

3. Slide the case top back and lift up.

4. To reinstall the case, reverse the procedure.

LINE VOLTAGE SELECTION

The Model 1541A oscilloscope is designed to work with a wide variety of line voltages. These voltages include, 110 V, 120 V, 220 V, 230 V, and 240 V at either 50 or 60 Hz. To select the desired line voltage, perform the following steps:

WARNING

Make sure the oscilloscope is unplugged before converting line voltage.

1. Remove the case by following the instructions in the previous paragraph titled "**CASE REMOVAL**".

2. Locate the line voltage printed circuit board at the back of the oscilloscope.

3. Carefully unplug the 5-pin socket (the largest of the three sockets plugged into the circuit board).

4. Connect the five pin socket to the pin header for the desired line voltage. The voltage range for each of the 5-pin headers is as follows:

   110 V - 99 V to 121 V
   120 V - 108 V to 132 V
   220 V - 198 V to 242 V
   230 V - 207 V to 253 V
   240 V - 216 V to 264 V

5. Be sure to use the proper fuse for the line voltage selected (see the **FUSE REPLACEMENT** paragraph located previ-

ously in this section of the instruction manual). Also, be sure to change fuse information lable if fuse value is changed

PERIODIC ADJUSTMENTS

Screwdriver adjustments only need to be checked and adjusted periodically. Probe compensation, and trace rotation are included in this category. Procedures are given below.

Probe Compensation

1. Connect probes to **CH 1 (X)** and **CH 2 (Y) INPUT** jacks. Repeat procedure for each probe.

2. Touch tip of probe to **CAL** terminal.

3. Adjust oscilloscope controls to display 3 or 4 cycles of **CAL** square wave at 5 or 6 divisions amplitude.

4. Adjust compensation trimmer on probe for optimum square wave (minimum overshoot, rounding off, and tilt). Refer to Fig. 27.

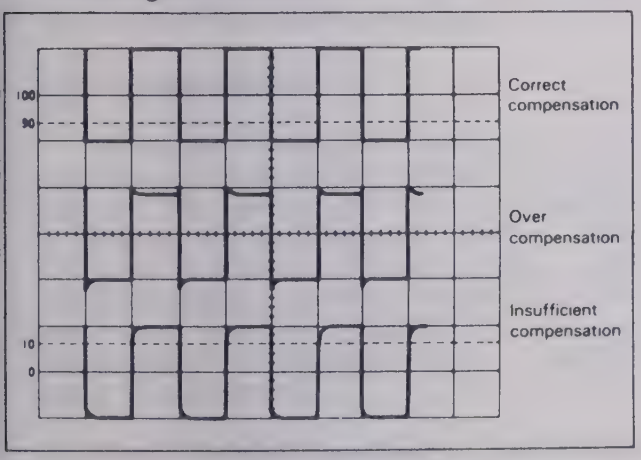

Fig. 27. Probe Compensation Adjustment.

Trace Rotation Adjustment

1. Set oscilloscope controls for a single trace display in **CH 1** mode, and with the channel 1 **AC-GND-DC** switch set to **GND.**

2. Use the channel 1 ⬍ **POS** control to position the trace over the center horizontal line on the graticule scale. The trace should be exactly parallel with the horizontal line.

3. Use the **TRACE ROTATION** adjustment on the front panel to eliminate any trace tilt.

CALIBRATION CHECK

A general check of calibration accuracy may be made by displaying the output of the **CAL** terminal on the screen. This terminal provides a square wave of 2.0 V p-p. This signal should produce a displayed waveform amplitude of four divisions at 0.5 V/div sensitivity for both channel 1 and 2 (with probes set for direct). With probes set for 10:1, there should be four divisions amplitude at 50 mV/div sensitivity. The volts/div and **SWEEP/VAR** controls must be set to **CAL** during this check.

*The **CAL** signal may be used only as a general check of calibration accuracy, not as a signal source for performing recalibration adjustments; a signal source of ± 0.3% or better accuracy is required for calibration adjustments.*

INSTRUMENT REPAIR SERVICE

Because of the specialized skills and test equipment required for instrument repair and calibration, many customers prefer to rely upon **B & K-Precision** for this service. We maintain a network of **B & K-Precision** authorized service agencies for this purpose. To use this service, even if the oscilloscope is no longer under warranty, follow the instructions given in the WARRANTY SERVICE INSTRUCTION portion of this manual. There is a nominal charge for instruments out of warranty.

APPENDIX I

IMPORTANT CONSIDERATIONS FOR RISE TIME AND FALL TIME MEASUREMENTS

Error In Observed Measurement

The observed rise time (or fall time) as seen on the CRT is actually the cascaded rise time of the pulse being measured and the oscilloscope's own risetime. The two rise times are combined in square law addition as follows:

$$T_{observed} \doteq \sqrt{(T_{pulse})^2 + (T_{scope})^2}$$

The effect of the oscilloscope's rise time is almost negligible when its rise time is at least 3 times as fast as that of the pulse being measured. Thus, slower rise times may be measured directly from the CRT. However, for faster rise time pulses, an error is introduced that increases progressively as the pulse rise time approaches that of the oscilloscope. Accurate measurements can still be obtained by calculation as described below.

Direct Measurements

The Model 1541A Oscilloscope has a rated rise time of 8.8 ns at 5 mV/div and higher sensitivity. Thus, pulse rise times of about 27 ns or greater can be measured directly. Most rise times are measured at the fastest sweep speed and using **X10 MAG.** For Model 1541A, this sweep rate is 20 ns/div. A rise time measurement of less than about 2 divisions should be calculated.

With **X5 MAG** selected (1 mV/div and 2 mV/div sensitivity), the rated rise time is increased to 17.5 ns. Pulse rise times must be at least 60 ns (for direct measurement on these ranges). Because of this, the **X5 MAG** mode of operation should be avoided for rise time measurements if possible.

Calculated Measurements

For observed rise times of less than 27 ns, the pulse rise time should be calculated to eliminate the error introduced by the cascaded oscilloscope rise time. Calculate pulse rise time as follows:

$$T_{pulse} \doteq \sqrt{(T_{observed})^2 - (T_{scope})^2}$$

Limits Of Measurement

Measurements of pulse rise times that are faster than the oscilloscope's rated rise time are not recommended because a very small reading error introduces significant error into the calculation. This limit is reached when the "observed" rise time is about 1.3 times greater than the scope's rated rise time, about 12 ns.

Probe Considerations

For fast rise time measurements which approach the limits of measurement, direct connection via 50 Ω coaxial cable and 50 Ω termination is recommended where possible. When a probe is used, its rise time is also cascaded in square law addition. Thus the probe rating should be considerably faster than the oscilloscope if it is to be disregarded in the measurement.

WARRANTY SERVICE INSTRUCTIONS
(For U.S.A. and its Overseas Territories)

1. Refer to the MAINTENANCE section of your **B & K-Precision** instruction manual for adjustments that may be applicable.

2. If the above-mentioned does not correct the problem you are experiencing with your unit, pack it securely (preferably in the original carton or double-packed). Enclose a letter describing the problem and include your name and address. Deliver to, or ship PREPAID (UPS preferred in U.S.A.) to the nearest **B & K-Precision** authorized service agency (see list enclosed with unit).

If your list of authorized **B & K-Precision** service agencies has been misplaced, contact your distributor for the name of your nearest service agency, or write to:

B & K-Precision, Dynascan Corporation
Factory Service Operations
6460 West Cortland Street
Chicago, Illinois 60635
Tel (312) 889-8870
Telex: 25-3475

Also use this address for technical inquiries
and replacement parts orders.

LIMITED TWO-YEAR WARRANTY

DYNASCAN CORPORATION warrants to the original purchaser that its **B & K-Precision** product, and the component parts thereof, will be free from defects in workmanship and materials for a period of two years from the date of purchase.

DYNASCAN will, without charge, repair or replace, at its option, defective product or component parts upon delivery to an authorized **B & K-Precision** service contractor or the factory service department, accompanied by proof of the purchase date in the form of a sales receipt.

To obtain warranty coverage in the U.S.A., this product must be registered by completing and mailing the enclosed warranty registration card to DYNASCAN, **B & K-Precision**, 6460 West Cortland Street, Chicago, Illinois 60635 within fifteen (15) days from the date of purchase.

Exclusions: This warranty does not apply in the event of misuse or abuse of the product or as a result of unauthorized alterations or repairs. It is void if the serial number is altered, defaced or removed.

DYNASCAN shall not be liable for any consequential damages, including without limitation damages resulting from loss of use. Some states do not allow limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

This warranty gives you specific rights and you may also have other rights which vary from state to state.

For your convenience we suggest you contact your **B & K-Precision** distributor, who may be authorized to make repairs or can refer you to the nearest service contractor. If warranty service cannot be obtained locally, please send the unit to **B & K-Precision** Service Department, 6460 West Cortland Street, Chicago, Illinois 60635, properly packaged to avoid damage in shipment.

B & K-Precision Test Instruments warrants products sold only in the U.S.A. and its overseas territories. In other countries, each distributor warrants the **B & K-Precision** products which it sells.

NOTES

BK PRECISION
DYNASCAN CORPORATION

6460 W. Cortland St. • Chicago, IL 60635
312-889-8870

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480-585-9-001

(GTE)

SERVICING INFORMATION

B&K PRECISION®

MODEL 1541A

40 MHz DUAL-TRACE OSCILLOSCOPE

PARTS LIST

FINAL ASSY

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	ELECTRICAL	
F1	1/2 Amp, 250V, 3AG Slow Blow Fuse (100 V,120 V)	190-251-3-102
F1	0.3 Amp, 250V, 3AG Slow Blow Fuse (220 V, 230 V, 240 V)	190-004-9-001
T602	Power Transformer	065-233-9-001
VR406/S501	10 kΩ, Potentiometer w/switch (VARIABLE, PULL 10 MAG)	008-881-9-003
VR501	10 kΩ Potentiometer (POSITION)	008-881-9-002
	150BYB31 CRT	230-039-9-001
	BNC Connector	772-024-9-001
	CRT Socket PC Board	303-136-9-001
	Cable Assembly (J34 to CAL)	428-182-9-001
	Cable Assembly (J5A to J5B)	428-182-9-002
	Cable Assembly (J15A to J15B)	428-182-9-003
	Cable Assembly (J32 to Z Axis INPUT)	428-182-9-004
	Cable Assembly (J1 to CH 1 OUTPUT)	428-182-9-005
	Cable Assembly (J13A to J13B and J25A to J25B)	428-182-9-006
	Cable Assembly (J9A to J9B)	428-182-9-007
	Cable Assembly (J21A to J21B)	428-182-9-008
	Cable Assembly (CRT to GND)	428-182-9-009
	Cable Assembly (Ground)	428-182-9-010
	Cable Assembly (J16 to POS.)	428-182-9-011
	Cable Assembly (J10 to EXT.)	428-182-9-012
	Cable Assembly (J18 to CRT)	428-182-9-013
	Cable Assembly (J19 to CRT)	428-182-9-014
	Cable Assembly, Twin Lead (J6 to CRT and J7 to CRT)	428-182-9-015
	Cable Assembly (J31 to CRT)	428-182-9-016
	Cable Assembly (J30 to CRT)	428-182-9-017
	Cable Assembly (J11A to J11B)	428-182-9-020
	Cable Assembly (J2A to J2B and J4A to J4B)	428-182-9-021
	Cable Assembly (J12A to J12B)	428-182-9-022
	Cable Assembly (J28A to J28B)	428-182-9-023
	Line Cord, 3 Wire CSA	420-013-9-001
	Trace Rotation Coil	040-008-9-001
	Wire Assembly (J14 to VAR.)	428-182-9-018
	Wire Assembly (J17 to X10 MAG Switch)	428-182-9-019
	Wire Assembly (J26A to J26B)	428-182-0-024
	Wire Assembly (J8A to J8B)	428-182-9-025
	Wire Assembly (J27A to J27B)	428-182-9-026
	Wire Assembly (J3A to J3B)	428-182-9-027
	MECHANICAL	
DS604, 605	Lamp Holder, Plastic	380-593-9-005
	AC Cord Wrap/Rear Foot	380-594-9-001
	CAL Terminal, Axis	777-086-9-001
	CAL Terminal, Washer	777-086-9-002
	CAL Terminal, Nut	777-086-9-003
	CAL Terminal, Bakelite Pipe	777-086-9-004
	CAL Terminal, Bakelite Axis	777-086-9-005
	CRT Bracket, Bottom	250-269-9-001
	CRT Bracket (Cross Brace)	254-127-9-006
	CRT Bracket, Top	250-269-9-002
	CRT Clip, Copper	741-206-9-002
	CRT Filter, Blue	380-593-9-001
	CRT Shield	256-274-9-001
	CRT Socket, 14 Pin	749-121-9-001
	CRT Socket Cover, Plastic	380-593-9-004
	Bottom Cover	252-065-9-001
	Bracket, Side	254-127-9-008
	Bracket (Small "Z" Shaped)	250-269-9-003
	Cable Tie	380-593-9-003
	Cover, Handle (Chrome)	746-076-9-003
	Clamp, Tilt Stand	741-206-9-001
	Dust Cover (AC/GND/DC Switch)	769-192-9-001
	Dust Cover (VERT MODE Switch)	769-192-9-002
	Dust Cover (SLOPE/COUPLING SOURCE Switch)	769-192-9-003
	Frame, Bottom Center	254-127-9-007
	Frame, Bottom Left	254-127-9-003
	Frame, Bottom Right	254-127-9-002
	Frame, Upper Center	254-127-9-004
	Frame, Upper Right	254-127-9-005
	Front Panel Bezel	380-595-9-001
	Front Panel Inlay	260-489-9-001
	Front Sub-Panel	254-127-9-001
	Fuse Holder	742-052-9-001
	Fuse Label, 1/2 A	483-699-9-003
	Ground Terminal	740-053-9-001
	Handle (Outer)	746-076-9-001
	High Voltage Shield Cover, Lower	256-274-9-002
	High Voltage Shield Plate	256-274-9-004
	Instruction Manual	480-585-9-001
	Knob, Gray, 16mm	751-312-9-001
	Knob, Gray w/Set Screw, 16mm (HOLD OFF)	751-340-9-001
	Knob, Dark Gray, w/Set Screw, 9.5mm (VOLT/DIV VAR.)	751-340-9-002
	Knob, Gray, w/Set Screw, 18mm (VOLTS/DIV)	751-340-9-003
	Knob, Gray, w/ Set Screw, 23mm (TIME/DIV)	751-340-9-004
	Knob, Dark Gray, 13mm (LEVEL)	751-341-9-001
	Label "CAUTION HIGH VOLTAGE"	483-699-9-001
	Lever Switch Knob, Gray	384-115-9-001
	Metal Insert, 3mm Thread (Front Panel)	758-046-9-001
	Nameplate LOGO, Front	260-488-9-001
	Pushbutton Switch Bezel	380-596-9-001
	Rear Panel	262-073-9-001
	Rubber Foot	381-152-9-001
	Rubber Pad (CRT Bracket)	381-178-9-001
	Rubber Pad 18 x 15mm (CRT Bezel)	381-178-9-002
	Rubber Pad 35 x 15mm (CRT Bezel)	381-178-9-003
	Rubber Pad (Under CRT Shield)	381-178-9-004
	Set Screw, 3 x 3mm x 0.5P (Knobs)	633-010-9-001

COMPOSITE
499-374-9-001

Pioneer
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FINAL ASSY (Continued)

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	Set Screw, 3 x 5mm x 0.5P (knobs)	633-010-9-002
	Snap Bushing (Trace Rotation)	380-593-9-002
	Standoff (Lever Switch)	759-232-9-001
	Standoff, 12.5mm long	759-232-9-004
	Standoff, 18.5mm long	759-232-9-005
	Steel Strap, Handle (Inner)	746-076-9-002
	Strain Relief	380-001-9-001
	Switch Button, Gray	384-115-9-002
	Switch Button, Red	384-079-9-003
	Tilt Stand, (Wire Form)	804-024-9-001
	Top Cover	253-145-9-001
	3 x 6mm, 0.5P Phillips Flat Head Machine Screw (Standoff Sub Panels and SubPanel Frames)	634-202-9-002
	3 x 6mm, 0.5P, Phillips Pan Head Machine Screw (Tilt Stand, PC Boards, Brackets, Case, Etc.)	634-202-9-006
	3 x 10mm, 0.5P Phillips Pan Head Machine Screw (Feet)	634-238-9-002
	3 x 12mm, 0.5P, Phillips Pan Head Machine Screw (Cord Wrap and CRT Clamp)	634-202-9-003
	3 x 14mm, 0.5P Phillips Flat Head Machine Screw (Handle)	634-202-9-009
	4 x 8mm, 0.7P Phillips Pan Head Machine Screw (Transformer)	634-240-9-001

SWEEP MODE SWITCH LINE SELECT...PC BOARD ASSEMBLY
546-027-9-001

RESISTORS

d resistors are ±5%, 1/4 W. See schematic diagram for value.

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	10 kΩ, 1/4 W, ±1% Metal Film	015-144-1-002
	10 kΩ, 1/4 W, ±1% Metal Film	015-144-1-002
706,	100 kΩ, 1/4 W, ±1% Metal Film	015-144-1-003
	10 kΩ, 1/4 W, ±1% Metal Film	015-144-1-002
	2.0 kΩ, 1/4 W, ±1% Metal Film	015-144-2-001
/S104	10 kΩ, Potentiometer w/Switch (CH1 POSITION/PULL CHOP ONLY)	008-881-9-005
/S204	10 kΩ, Potentiometer w/Switch (CH2 POSITION/PULL INVERT)	008-881-9-005
/S406	10 kΩ/100 kΩ Dual Potentiometer w/Switch (LEVEL, HOLD OFF / ALT/CHOP SWITCH)	008-881-9-006
	10 kΩ Potentiometer (INTEN)	008-881-9-004
	200 kΩ, Potentiometer (FOCUS)	008-881-9-001
	10 kΩ Potentiometer (ILLUM)	008-881-9-004
	2 kΩ Potentiometer (ROTATION)	008-881-9-007
	100 kΩ Trimmer Potentiometer (FREQUENCY)	010-061-9-001

CAPACITORS

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	1000 pF, ±10%, 50 V, Ceramic	020-430-9-001
	0.1 µF, +80/–20%, 50 V, Ceramic	020-430-9-002
602	1000 pF, +80/–20%, 6.3 KV, Ceramic	020-430-9-003
	47 µF, +80/–20%, 25 V, Electrolytic	022-328-9-001
C702, 703	.01 µF,±1%, 100 V, Metalized, Polyester	025-250-9-002
C704	1 pF,±0.5 pF, 50 V, NPO Ceramic	031-073-9-001
C705	220 pF,±5%, 50 V, NPO Ceramic	031-073-9-002

SWITCHES

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
S302, S404	Pushbutton Switch, 4 Station (ALT, AUTO/NORM/SINGLE)	088-178-9-002
S601	Pushbutton Switch, 1 Station (ON/OFF)	088-178-9-001

DIODES

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
D405	1N4148	151-038-9-001
DS401, 603	LED, Red	158-076-9-001
DZ606 – 609	36 V, 2.2%, 500 mW, Zener	152-186-9-001

TRANSISTORS

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
Q614, 615	2SC1846R NPN	176-142-9-002

INTEGRATED CIRCUITS

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
U701	4011B Quad 2-Input NAND Gate	308-144-9-001

MISCELLANEOUS

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
DS604, 605	14 V, 80 mA Lamp	400-101-9-001
J9B, 13B	2 Pin PC Terminal, Right Angle Small	757-147-9-002
J21A	2 Pin PC Terminal, Large	757-148-9-002
J21B	2 Pin PC Terminal (Special)	757-147-9-001
J22	3 Pin PC Terminal, Large	757-148-9-003
J23A – 23E	5 Pin PC Terminal, Large	757-148-9-005
J33, 34	2 Pin IC Terminal, Small	757-144-9-002
	Shield, 18 x 47mm	256-274-9-003

VERTICAL INPUT OUTPUT, POWER SUPPLY & SWITCHING CIRCUIT PC BOARD ASSY
546-026-9-001

RESISTORS

d resistors are ±5%, 1/4 W. See schematic diagram for value.

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	1 MΩ, ±1%, 1/2 W, Metal Film	015-124-1-004
	900 kΩ, ±1%, 1/2 W, Metal Film	013-010-9-011
	111 kΩ, ±1%, 1/4 W, Metal Film	013-034-9-036
	990 kΩ, ±1%, 1/2 W, Metal Film	013-010-9-012
	10.1 kΩ, ±1%, 1/4 W, Metal Film	013-034-9-035
	470 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-474
	Resistor Network	012-047-9-002
126	121 Ω, ±1%, 1/4 W, Metal Film	015-144-1-210
	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
	56.2 kΩ, ±1%, 1/4 W, Metal Film	015-144-5-622
	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
	56.2 kΩ, ±1%, 1/4 W, Metal Film	015-144-5-622
140	681 Ω, ±1%, 1/4 W, Metal Film	015-144-6-810
148	1.54 kΩ, ±1%, 1/4 W, Metal Film	014-144-1-541
155	1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-001
	1 MΩ, ±1%, 1/2 W, Metal Film	015-124-1-004
	900 kΩ, ±1%, 1/2 W, Metal Film	013-010-9-011
	111 kΩ, ±1%, 1/4 W, Metal Film	013-034-9-036
	990 kΩ, ±%, 1/2 W, Metal Film	013-010-9-012
	10.1 kΩ, ±1%, 1/4 W, Metal Film	013-034-9-035
	470 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-474
	Resistor Network	012-047-9-002
226,	121 Ω, ±1%, 1/4 W, Metal Film	015-144-1-210
	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
R233	56.2 kΩ, ±1%, 1/4 W, Metal Film	015-144-5-622
R235	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
R236	56.2 kΩ, ±1%, 1/4 W, Metal Film	015-144-5-622
R239, 240	681 Ω, ±1%, 1/4 W, Metal Film	015-144-6-810
R247, 248	1.54 kΩ, ±1%, 1/4 W, Metal Film	014-144-1-541
R254, 255	1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-001
R303, 304	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
R310	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
R311, 312	90.9 Ω, ±1%, 1/4 W, Metal Film	015-144-9-098
R313	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
R315	90.9 Ω, ±1%, 1/4 W, Metal Film	015-144-9-098
R325, 326	33 kΩ, ±5%, 1 W, Metal Oxide	011-001-5-333
R328, 329	47 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-473
R355	10 kΩ, ±5%, Resistor Network	012-047-9-003
R600, 601	3.9 kΩ, ±5%, 2 W, Metal Oxide	004-236-9-004
R603	100 Ω, ±5%, 1 W, Metal Oxide	011-001-5-101
R607	121 kΩ, ±1%, 1/2 W, Metal Film	015-124-1-213
R608	10.1 kΩ, ±0.5%, 1/4 W, Metal Film	017-144-1-012
R609	1.0 Ω, ±5%, 1 W, Metal Oxide	011-001-5-109
R612	2.2 Ω, ±5%, 1/2 W, Carbon Film	002-102-5-229
R613	100 Ω, ±5%, 1 W, Metal Oxide	011-001-5-101
R614	68 Ω, ±5%, 1 W, Metal Oxide	011-001-5-680
R616	3.92 kΩ, ±1%, 1/4 W, Metal Film	015-144-3-921
R617	9.09 kΩ, ±1%, 1/4 W, Metal Film	015-144-9-091
R619	12.1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-212
R622	12.1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-212
R623	100 Ω, ±5%, 1 W, Metal Oxide	011-001-5-101

VERTICAL INPUT OUTPUT, POWER SUPPLY & SWITCHING CIRCUIT PC BOARD ASSY (Continued)

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
4, 625	2.2 MΩ, ±5%, 1/2 W, Carbon Film	002-102-5-225
01, 102, 01	250 Ω, ±15%, Thermistor	005-022-9-001
01	22 kΩ, Trimmer Potentiometer (STEP BAL)	010-061-9-010
02	100 Ω, Trimmer Potentiometer (X5 GAIN)	010-061-9-006
03	470 Ω, Trimmer Potentiometer (1ST COMP)	010-061-9-011
04	22 kΩ, Trimmer Potentiometer (MAG DC BAL)	010-061-9-010
06	22 kΩ, Trimmer Potentiometer (VAR DC BAL)	010-061-9-010
07	220 Ω, Trimmer Potentiometer (2ND COMP)	010-061-9-008
08	1 kΩ, Trimmer Potentiometer (CH1 GAIN)	010-061-9-007
09	100 Ω, Trimmer Potentiometer (X-GAIN)	010-061-9-006
10	1 kΩ, Trimmer Potentiometer (CH1 TRIG DC OFFSET)	010-061-9-007
12	2.2 kΩ, Trimmer Potentiometer (SIGNAL OUT DC OFFSET)	010-061-9-009
01	22 kΩ, Trimmer Potentiometer (STEP BAL)	010-061-9-010
02	100 Ω, Trimmer Potentiometer (X GAIN)	010-061-9-006
03	470 Ω, Trimmer Potentiometer (1ST COMP)	010-061-9-011
04	22 kΩ, Trimmer Potentiometer (MAG DC BAL)	010-061-9-010
06	22 kΩ, Trimmer Potentiometer (VAR DC BAL)	010-061-9-010
07	220 Ω, Trimmer Potentiometer (2ND COMP)	010-061-9-008
08	1 kΩ, Trimmer Potentiometer (CH2 GAIN)	010-061-9-007
10	1 kΩ, Trimmer Potentiometer (CH2 TRIG DC OFFSET, STEP BAL)	010-061-9-007
01	470 Ω, Trimmer Potentiometer (ADD BAL)	010-061-9-011
02	2.2 kΩ, Trimmer Potentiometer (3RD COMP)	010-061-9-009
01	1 kΩ, Trimmer Potentiometer (+12 V ADJ)	010-061-9-007
	CAPACITORS	
	100 pF, ±5%, 50 V, NPO Ceramic	201-069-9-003
2	22 pF, ±5%, 50 V, NPO Ceramic	031-068-9-003
3	100 pF, ±5%, 50 V, NPO Ceramic	201-069-9-003
4	68 pF, ±5%, 50 V, NPO Ceramic	031-073-9-012
5	5 pF, ±0.5 pF, 500 V, NPO Ceramic	031-073-9-008
1	100 pF, ±5%, 50 V, NPO Ceramic	201-069-9-003
2	22 pF, ±5%, 50 V, NPO Ceramic	031-068-9-003
3	100 pF, ±5%, 50 V, NPO Ceramic	201-069-9-003
4	68 pF, ±5%, 50 V, NPO Ceramic	031-073-9-012
01	.022 µF, ±5%, 630 V, Metal Film Polyester	025-282-9-009
02	33 pF, ±5%, 500 V, NPO Ceramic	031-073-9-010
03	270 pF, ±5%, 50 V, NPO Ceramic	031-073-9-006
04	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
05	2200 pF, ±5%, 400 V, Metalized Film Polyester	025-282-9-008
06	10 pF, ±5%, 500 V, NPO Ceramic	031-073-9-009
07	1000 pF, ±10%, 500 V, Ceramic	020-430-9-006
08, 109	0.1 µF, +80/–20%, 50 V, Ceramic	020-430-9-002
0	1000 pF, ±10%, 500 V, Ceramic	020-430-9-006
1	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
2	15 pF, ±5%, 500 V, NPO Ceramic	031-073-9-004
3	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
4, 115	5 pF, ±0.5 pF, 500 V, NPO Ceramic	031-073-9-008
6, 117	82 pF, ±5%, 50 V, NPO Ceramic	031-073-9-007
8	47 pF, 500 V, NPO Ceramic	031-073-9-005
9, 120, 22	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
23	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
24	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
25, 126	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
C127	22 pF, ±5%, 50 V, NPO Ceramic	031-068-9-003
C128	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C201	.022 µF, ±5%, 630 V, Metalized Film Polyester	025-282-9-009
C202	33 pF, ±5%, 500 V, NPO Ceramic	031-073-9-010
C203	270 pF, ±5%, 50 V, NPO Ceramic	031-073-9-006
C204	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
C205	2200 pF, ±5%, 400 V, Metalized Film Polyester	025-282-9-008
C206	10 pF, ±5%, 500 V, NPO Ceramic	031-073-9-009
C207	1000 pF, ±10%, 500 V, Ceramic	020-430-9-006
C208, 209	0.1 µF, +80/–20%, 50 V, Ceramic	020-430-9-002
C210	1000 pF, ±10%, 500 V, Ceramic	020-430-9-006
C211	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C212	15 pF, ±5%, 500 V, NPO Ceramic	031-073-9-004
C213	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
C214, 215	5 pF, ±0.5 pF, 500 V, NPO Ceramic	031-073-9-008
C216, 217	82 pF, ±5%, 50 V, NPO Ceramic	031-073-9-007
C218	47 pF, 500 V, NPO Ceramic	031-073-9-005
C219, 220, 222, 224	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
C225, 226	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
C227	22 pF, ±5%, 50 V, NPO Ceramic	031-068-9-003
C228	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C301	5 pF, ±0.5 pF, 500 V, NPO Ceramic	031-073-9-008
C302, 303	15 pF, ±5%, 500 V, NPO Ceramic	031-073-9-004
C304, 305	.01 µF, ±5%, 100 V, Polyester	025-282-9-006
C306, 307	0.47 pF, 0.25 pF, 500 V, NPO Ceramic	031-073-9-011
C308, 309	.047 µF, ±5%, 250 V, Metalized Film Polyester	025-282-9-007
C310	0.1 µF, +80/–20%, 50 V, Ceramic	020-430-9-002
C311	.022 µF, ±5%, 630 V, Metalized Film Polyester	025-282-9-009
C312	0.1 µF, ±5%, 100 V, Polyester	025-282-9-002
C313	.022 µF, ±5%, 630 V, Metalized Film Polyester	025-282-9-009
C314	1.0 µF, +80/–20%, 160 V, Electrolytic	021-085-9-001
C315, 316	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
C317	1500 pF, ±10%, 50 V, Ceramic	020-430-9-009
C318	1000 pF, ±10%, 500 V, Ceramic	020-430-9-006
C319, 320	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
C321, 322	100 µF, +80/–20%, 25 V, Electrolytic	022-328-9-002
C323, 324	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C325	10 pF, ±5%, 500 V, NPO Ceramic	031-073-9-009
C603	47 µF, +80/–20%, 200 V, Electrolytic	021-085-9-002
C604	4.7 µF, +80/–20%, 350 V, Electrolytic	021-085-9-003
C605	1.0 µF, +80/–20%, 160 V, Electrolytic	021-085-9-001
C606	47 µF, +80/–20%, 25 V, Electrolytic	022-328-9-001
C607, 608	1000 µF, +80/–20%, 25 V, Electrolytic	022-335-9-004
C609, 610	.022 µF, ±5%, 100 V, Polyester	025-282-9-003
VC101	3-10 pF Trimmer	028-114-9-002
VC102	2.5-6 pF Trimmer	028-114-9-001
VC103	4.5-20 pF Trimmer	028-114-9-003
VC104	2.5-6 pF Trimmer	028-114-9-001
VC105	4.5-20 pF Trimmer	028-114-9-003
VC106	7.5-50 pF Trimmer	028-114-9-004
VC201	3-10 pF Trimmer	028-114-9-002
VC202	2.5-6 pF Trimmer	028-114-9-001
VC203	4.5-20 pF Trimmer	028-114-9-003
VC204	2.5-6 pF Trimmer	028-114-9-001
VC205	4.5-20 pF Trimmer	028-114-9-003
VC206	7.5-50 pF Trimmer	028-114-9-004
VC301	4.5-20 pF Trimmer	028-114-9-003
	SWITCHES	
S101	3 Position Lever Switch (AC GND DC)	080-031-9-003
S103/VR105	Rotary Switch w/Potentiometer (VOLTS/DIV Attenuator)	083-325-9-001
S201	3 Position Lever Switch (AC GND DC)	080-031-9-003
S203/VR205	Rotary Switch w/Potentiometer (VOLTS/DIV Attenuator/PULL X5 MAG / VARIABLE)	083-325-9-001
S301	4 Position Lever Switch (VERT MODE)	080-031-9-001

VERTICAL INPUT OUTPUT, POWER SUPPLY & SWITCHING CIRCUIT PC BOARD ASSY (Continued)

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	DIODES	
BD601, 602	2 A, 600 V, Bridge (2W06M)	157-039-9-001
D101 – 107, 201 – 206, 301 – 316, 601, 602	1N4148	151-038-9-001
DZ101, 201	3.3 V, ±3%, 500 mW, Zener	152-186-9-003
DZ301, 302	2.2 V, ±4.5%, 500 mW, Zener	152-186-9-002
DZ601, 602	13 V, +4.7/–3.1%, 500 mW, Zener	152-186-9-005
DZ603	5.6 V, +1.79/–2.5%, 500 mW, Zener	152-186-9-004
	TRANSISTORS	
Q101	2SC1730K NPN	176-222-9-001
Q102	2SK121-3 FET	182-101-9-002
Q103	2SC945Q NPN	176-059-9-003
Q104	2SA844D PNP	177-021-9-001
Q105	2SC945Q NPN	176-059-9-003
Q106, 107	2SA1206K PNP	177-065-9-001
Q108, 109	2SA838C PNP	177-036-9-001
Q110	2SC1730K NPN	176-222-9-001
Q111, 112	2SA838C PNP	177-036-9-001
Q201	2SC1730K NPN	176-222-9-001
Q202	2SK121-3 FET	182-101-9-002
Q203	2SC945Q NPN	176-059-9-003
Q204	2SA844D PNP	177-021-9-001
Q205	2SC945Q NPN	176-059-9-003
Q206, 207	2SA1206K PNP	177-065-9-001
Q208 – 213	2SA838C PNP	177-036-9-001
Q301, 302	2SA1206K PNP	177-065-9-001
Q303 – 305	2SC1730K NPN	176-222-9-001
Q306, 307	2SA1206K PNP	177-065-9-001
Q308	2SC1730K NPN	176-222-9-001
Q309	2SA1360-0 PNP	173-024-9-002
Q310, 311	2SC3423-0 NPN	172-082-9-004
Q312	2SA1360-0 PNP	173-024-9-002
Q313, 314	2SC2570A NPN	176-222-9-003
Q315, 316	2SA844D PNP	177-021-9-001
Q601	2SB861C PNP	173-024-9-003
Q602	2SD880Y NPN Power	172-082-9-001
Q603	2SB834Y PNP Power	173-024-9-004
Q604	2SD880Y NPN Power	172-082-9-001
	INTEGRATED CIRCUITS	
U101	3140 Operational Amplifier	308-191-9-001
U102	3086 Transistor Array	307-087-9-001
U201	3140 Operational Amplifier	308-191-9-001
U202	3086 Transistor Array	307-087-9-001
U301	74LS74AN Dual D Flip-Flop	307-361-9-006
U302 – 304	74S00N Quad 2-Input NAND Gate	307-100-9-001
U601, 602	4558C BCD-TO-7 Segment Decoder	307-435-9-003
	INDUCTORS AND TRANSFORMERS	
L301, 302	0.14 µH, ±20% Coil	047-075-9-002
	MISCELLANEOUS	
J1	2 Pin PC Terminal, Small	757-144-9-002
J2A, 4A	5 Pin PC Terminal, Small	757-149-9-002
J5A	2 Pin PC Terminal, Small	757-144-9-002
J6, 7	1 Pin PC Terminal, Large	757-148-9-001
J8A	4 Pin PC Terminal, Small	757-149-9-003
J9A	2 Pin PC Terminal, Small	757-144-9-002
J24	5 Pin PC Terminal, Large	757-148-9-005
J25A	2 Pin PC Terminal, Small	757-144-9-002
J26A	5 Pin PC Terminal, Small	757-149-9-002
J27A, 28A	6 Pin PC Terminal, Small	757-149-9-004
	Heat Sink (for Q309 – 312)	747-164-9-002
	Heat Sink (for Q601, 603, 604)	747-164-9-003
	Heat Sink	747-164-9-004
	Insulator, Transistor	347-140-9-001

HORIZ SWEEP, TRIGGER & HIGH VOLTAGE PC BOARD ASSEMBLY 546-025-9-001

SCHEMATIC SYMBOL	DESCRIPTION	B & K-PRECISION PART NO.
	RESISTORS	
	Unlisted resistors are ±5%, 1/4 W. See schematic diagram for value.	
R402	1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-001
R411	1 MΩ, ±1%, 1/2 W, Metal Film	015-124-1-004
R417, 418	681 Ω, ±1%, 1/4 W, Metal Film	015-144-6-810
R459	33.2 kΩ, ±1%, 1/4 W, Metal Film	015-144-3-322
R460	22.1 kΩ, ±1%, 1/4 W, Metal Film	015-144-2-212
R474	2.21 kΩ, ±1%, 1/4 W, Metal Film	015-144-2-211
R481	Resistor Network	012-047-9-001
R483	1.62 kΩ, ±1%, 1/4 W, Metal Film	014-144-1-621
R486	475 Ω, ±1%, 1/4 W, Metal Film	015-144-4-750
R487	3.92 kΩ, ±1%, 1/4 W, Metal Film	015-144-3-921
R503	56.2 Ω, ±1%, 1/4 W, Metal Film	015-144-5-628
R504 – 507	5.62 kΩ, ±1%, 1/4 W, Metal Film	015-144-5-621
R508 – 510	1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-001
R511	562 Ω, ±1%, 1/4 W, Metal Film	015-144-5-620
R512, 513	332 Ω, ±1%, 1/4 W, Metal Film	015-144-3-320
R515	100 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-104
R516	100 kΩ, ±1%, 1/2 W, Metal Film	015-124-1-003
R518	100 kΩ, ±1%, 1/2 W, Metal Film	015-124-1-003
R523	100 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-104
R626	100 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-003
R630	8.25 kΩ, ±1%, 1/4 W, Metal Film	015-144-8-251
R631	12.1 kΩ, ±1%, 1/4 W, Metal Film	015-144-1-212
R634	1.0 Ω, ±1%, 1 W, Metal Oxide	004-236-9-002
R638	2.2 MΩ, ±5%, 1/2 W, Carbon Film	002-102-5-225
R639, 640	10 MΩ, ±5%, 1/2 W, Carbon Film	002-102-5-106
R645	1.5 MΩ, ±5%, 1/2 W, Carbon Film	002-102-5-155
R646	6.8 MΩ, ±1%,, 1.6 W, Metal Glaze	004-236-9-003
R647	10 MΩ, ±1%, 2.5 W, Metal Glaze	004-236-9-001
R648, 649	10 MΩ, ±5%, 1/2 W, Carbon Film	002-102-5-106
R651	1.5 MΩ, ±5%, 1/2 W, Carbon Film	002-102-5-155
R657, 658	47 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-473
R661, 662	47 kΩ, ±5%, 1/2 W, Carbon Film	002-102-5-473
R670	100 kΩ, ±1%, 1/4 W, Metal Film	015 144-1-003
VR401	47 kΩ, Trimmer Potentiometer (X-AXIS DC-OFFSET)	010-061-9-004
VR403	10 kΩ, Trimmer Potentiometer (TRIG BAL)	010-061-9-002
VR404	470 kΩ, Trimmer Potentiometer (1µS ADJ)	010-061-9-005
VR405	10 kΩ, Trimmer Potentiometer (1mS ADJ)	010-061-9-002
VR602	2.2 MΩ, Trimmer Potentiometer (SUB FOCUS)	010-061-9-003
VR603	10 kΩ, Trimmer Potentiometer (SUB INTEN)	010-033-9-003
VR604	100 kΩ, Trimmer Potentiometer (ASTIG)	010-061-9-001
	CAPACITORS	
C402	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
C403	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C404	.022 µF, ±5%, 100 V, Polyester	025-282-9-003
C405, 406	47 pF, ±5%, 500 V, NPO Ceramic	031-073-9-005
C407	470 pF, ±10%, 50 V, Ceramic	020-430-9-008
C408,	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C410, 411	47 µF, +80/–20%, 25 V, Electrolytic	022-328-9-001
C412	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C413	1.0 µF, ±10%, 35 V, Tantalum	027-096-9-001
C414	100 µF, +80/–20%, 25 V, Electrolytic	022-328-9-002
C415	0.1 µF, ±5%, 100 V, Polyester	025-282-9-002
C416	47 pF, ±5%, 500 V, NPO Ceramic	031-073-9-005
C417	47 µF, +80/–20%, 25 V, Electrolytic	022-328-9-001
C420, 422	1000 pF, ±10%, 500 V, Ceramic	020-430-9-006
C421	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
C423	.01 µF, ±5%, 100 V, Polyester	025-282-9-001
C424	47 pF, ±5%, 500 V, NPO Ceramic	031-073-9-005
C425	47 µF, +80/–20%, 25 V, Electrolytic	022-328-9-001
C426	1000 pF, ±5%, 100 V, Metal Film Polyester	025-282-9-004
C427	100 pF, ±5%, 50 V, NPO Ceramic	031-069-9-003
C428	1.0 µF, ±5%, 100 V, Metalized Film Polyester	025-282-9-005
C429	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
C430	15 pF, ±5%, 500 V, NPO Ceramic	031-073-9-004
C431	47 µF, +80/–20%, 25 V, Electrolytic	022-328-9-001

HORIZ SWEEP, TRIGGER & HIGH VOLTAGE PC BOARD ASSEMBLY (Continued)

CHEMATIC YMBOL	DESCRIPTION	B & K-PRECISION PART NO.
432	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
433, 434	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
435	100 pF, ±5%, 50 V, NPO Ceramic	031-069-9-003
501	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
502 – 506	.01 µF, +80/–20%, 500 V, Ceramic	020-430-9-007
507	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
611	1.0 µF, ±10%, 35 V, Tantalum	027-096-9-001
612	4700 pF, ±10%, 50 V, Ceramic	020-430-9-005
613	.022 µF, ±5%, 100 V, Polyester	025-282-9-003
614	200 µF, +80/–20%, 50 V, Electrolytic	022-390-9-002
618	4700 pF, +80/–20%, 3 KV, Ceramic	020-430-9-004
619	1000 pF, +80/–20%, 6.3 KV, Ceramic	020-430-9-003
620	.01 µF, +80/–20%, 500 V, Ceramic	020-430-9-007
621 – 625	1000 pF, +80/–20%, 6.3 KV, Ceramic	020-430-9-003
626	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
627	.01 µF, +80/–20%, 500 V, Ceramic	020-430-9-007
628	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
629	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
630	220 pF, ±5%, 50 V, NPO Ceramic	031-073-9-002
631	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
632	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
633	.01 µF, +80/–20%, 500 V, Ceramic	020-430-9-007
634	.022 µF, ±5%, 100 V, Polyester	025-282-9-003
635, 636	10 µF, +80/–20%, 50 V, Electrolytic	022-390-9-001
637	22 pF, ±10%, 2 KV, NPO Ceramic	031-073-9-003
638	.01 µF, +80/–20%, 50 V, Ceramic	020-380-9-001
	SWITCHES	
401, 402	Lever Switch (SOURCE, COUPLING)	080-031-9-002
403	Lever Switch (SLOPE)	080-031-9-001
405	Rotary Switch (TIME/DIV)	083-324-9-001
	DIODES	
401, 402	1N4148	151-038-9-001
403	1SS86 (30 mA, 3 V)	151-156-9-002
404, 406, 407	1N4148	151-038-9-001
408	1SS86 (30 mA, 3 V)	151-156-9-002
409 – 420	1N4148	151-038-9-001
501	1SS86 (30 mA, 3 V)	151-156-9-002
502, 503	1N4148	151-038-9-001
D504	1SS83 (200 mA, 250 V)	151-084-9-001
603, 605, 6,	1N4148	151-038-9-001
609 – 613	1SS83 (200 mA, 250 V)	151-084-9-001
614	200 mA, 2 KV	151-156-9-001
615, 616	1SS83 (200 mA, 250 V)	151-084-9-001
617 – 620	1N4148	151-038-9-001
Z401	3.3 V, ±3%, 500 mW, Zener	152-186-9-003
Z402	5.6 V, +1.79/–2.5%, 500 mW, Zener	152-186-9-004
Z604, 605	2.2 V, ±4.5%, 500 mW, Zener	152-186-9-002
Z610	5.6 V, +1.79/–2.5%, 500 mW, Zener	152-186-9-004
	TRANSISTORS	
401, 402	2SA838C PNP	177-036-9-001
403	2SK121-3 FET	182-101-9-002
404, 405	2SC1730K NPN	176-222-9-001
406 – 409	2SA844D PNP	177-021-9-001
Q410	2SK40C FET	182-101-9-003
Q411	2SK117BL FET	182-101-9-001
Q412	2SA1015-GR PNP	177-057-9-001
Q413	2SA838C PNP	177-036-9-001
Q414, 415	2SC1730K NPN	176-222-9-001
Q416	2SA844D PNP	177-021-9-001
Q417	2SC945Q NPN	176-059-9-003
Q418	2SC1730K NPN	176-222-9-001
Q419, 420	2SC945Q NPN	176-059-9-003
Q421, 422	2SA844D PNP	177-021-9-001
Q423	2SC945Q NPN	176-059-9-003
Q424	2SA844D PNP	177-021-9-001
Q425, 426	2SK117BL FET	182-101-9-001
Q427	2SC945Q NPN	176-059-9-003
Q428	2SA844D PNP	177-021-9-001
Q429	2SC1843E NPN	176-222-9-002
Q430, 431	2SA844D PNP	177-021-9-001
Q501, 502	2SA1015-GR PNP	177-057-9-001
Q503, 504	2SC945Q NPN	176-059-9-003
Q505 – 507	2SC1730K NPN	176-222-9-001
Q508	2SA838C PNP	177-036-9-001
Q509	2SB648A-B PNP Power	173-024-9-001
Q510, 511	2SD668A-C NPN Power	172-082-9-003
Q512	2SB648A-B PNP Power	173-024-9-001
Q605	2SD880Y NPN Power	172-082-9-001
Q606 – 609	2SC2371K NPN Power	172-082-9-002
Q610, 611	2SC1730K NPN	176-222-9-001
Q612	2SA844D PNP	177-021-9-001
Q613	2SK117BL FET	182-101-9-001
	INTEGRATED CIRCUITS	
U401	74S00 Quad 2-Input NAND Gate	307-028-9-001
U402	74LS112AN Dual JK Flip-Flop	307-259-9-025
U403	TL081CP Operational Amplifier	307-464-9-001
U404	Triple 2CH Analog Multiplexer	308-375-9-003
U603	TL081CP Operational Amplifier	307-464-9-001
	INDUCTORS AND TRANSFORMERS	
L601	100 µH, ±10% Coil	047-075-9-001
T601	Pulse Transformer	064-032-9-001
	MISCELLANEOUS	
DS601, 602	NE-2 Neon Lamp	401-002-9-001
J5B	2 Pin PC Terminal, Small	757-144-9-002
J10	1 Pin PC Terminal, Large	757-148-9-001
J11A, 12A	5 Pin PC Terminal, Small	757-149-9-002
J13A	2 Pin PC Terminal, Small	757-144-9-002
J14	3 Pin PC Terminal, Small	757-149-9-001
J15A, 15B,	2 Pin PC Terminal, Small	757-144-9-002
J16, 17	3 Pin PC Terminal, Small	757-149-9-001
J18, 19	1 Pin PC Terminal, Large	757-148-9-001
J25B	2 Pin PC Terminal, Small	757-144-9-002
J29	2 Pin PC Terminal, Large	757-148-9-002
J30	5 Pin PC Terminal, Large	757-148-9-005
J31	3 Pin PC Terminal, Large	757-148-9-003
J32	2 Pin PC Terminal, Small	757-144-9-002
	Heat Sink	747-164-9-001
	Insulator, Transistor (For Q605)	347-140-9-001
	Multiplier Assembly	524-020-9-001

CALIBRATION PROCEDURE

WARNING

The following instructions are for use by qualified service personnel only. To avoid electrical shock, do not perform servicing unless qualified to do so.

High voltage up to 12 kV when covers are removed and the unit is operating. Remember that high voltage may be retained indefinitely on high voltage capacitors. Also remember that ac line voltage is present on line voltage input circuits (including the fuse holder, line cord receptacle, and POWER switch) anytime the instrument is plugged into an ac outlet, even if turned off. Unplug the oscilloscope and discharge high voltage capacitors before performing service procedures unless it is necessary to have the unit powered up.

NERAL

unit was carefully checked and calibrated at the factory prior to ment. After the oscilloscope has been used for a period of time, it uld be calibrated to maintain instrument accuracy. Calibration is required if repairs have been made in a circuit affecting calibration. location of the calibration adjustments is shown in Fig. 1 and Fig. Keep in mind that some calibration adjustments require high ision test instruments. Those adjustments should be attempted if the proper test equipment is available and you are experienced use. The unit should be calibrated at an ambient temperature of egrees C (± 5 degrees C). Before making adjustments connect the to AC line voltage, 50/60 Hz line source and allow at least 30 utes of warmup time before proceeding. The following test equip- t is required for complete calibration:

B & K-Precision Model 2906 Multimeter or equivalent.

B & K-Precision Model 1400 Oscilloscope Calibrator or equivalent.

B & K-Precision Model 1655 Variable AC Power Supply or equivalent with 120 V, 3 A capacity.

B & K-Precision Model PR-28 High Voltage Multiplier Probe or equivalent with capability of measuring at least 12 kV.

NOTE

All voltage measurements are to be taken with respect to earth (chassis) ground unless otherwise noted.

djusting procedures MUST be done in sequence.

WER SUPPLY ADJUSTMENTS

e you start to calibrate the oscilloscope, its DC supply voltage d be checked and adjusted.

SUPPLY

k the +12 V supply voltage and adjust if necessary. The other y voltages should be checked and adjusted only after the +12 V tment has been completed.

Connect the digital voltmeter (DVM) between +12V and ground. If necessary, adjust 12V ADJ for a +12 V ± 0.05 V reading on the voltmeter.

VOLTAGE SUPPLY

Connect the DVM between –12V and ground. Acceptable limits are –12 V ± 0.2 V.

Connect the DVM between +5V and ground. Acceptable limits are +5 V ± 0 25 V.

Connect the DVM between +145V and ground. Acceptable limits are +145 V ± 5 V.

VOLTAGE SUPPLY(S)

Connect the DVM between –HV and ground.

Measure the voltage using a high voltage probe. Acceptable limits are between –1725 V and –1875 V.

The output of the multiplier should be approximately +10 kV

CIRCUIT ADJUSTMENT

ISITY ADJUSTMENT

Set up the oscilloscope with the **TIME/DIV** switch set to **1 mS** to display a single horizontal trace on the screen.

2. Turn the **HOLD OFF** knob to **NORM** and set the white mark of the **INTENSITY** control to the 10 o'clock position.
3. Adjust VR603 (SUB INTEN) until the trace displayed on the screen is just barely visible.

FOCUS ADJUSTMENT

1. Set up the oscilloscope with the **FOCUS** control set to display the white dot in the upright or noon position.
2. Adjust VR602 (SUB FOCUS) to obtain the best focus.

ASTIGMATISM ADJUSTMENT

1. Set up the oscilloscope with the **TIME/DIV** switch set to **X-Y** and the input coupling switch set to GND.
2. Use the position controls to display the beam spot in the center of the CRT screen.
3. Set the **INTENSITY** control for a small spot and turn the **FOCUS** control to obtain the sharpest image possible.
4. Adjust VR604 (ASTIG) so that the shape of the beam spot becomes as true a circle as possible.

VERTICAL SYSTEM ADJUSTMENT

DC BALANCE ADJUSTMENT

1. Set the channel 1 (CH 1) [channel 2 (CH 2)] **AC-GND-DC** switch to **GND** and the **VERT MODE** switch to **CH 1 [CH 2]** to display the trace on the CRT screen.
2. Set the **VOLTS/DIV** switch to **5 mV**.
3. Position the trace to the horizontal center line and then change the **VOLTS/DIV** switch to **10 mV**.
4. Check that the trace is within ± 0.05 division of the center horizontal line.
5. Adjust VR101 [VR201] (STEP BAL) for a trace at the center line.
6. Repeat steps 2 through 5 until a division shift of less than ± 0.05 is noted when changing the **VOLTS/DIV** setting.
7. Check the trace division for the other **VOLTS/DIV** ranges. The trace for each range must be within ± 0.15 of the center horizontal line.
8. Repeat procedure for CH 2 using data shown in brackets.

X5 MAGNIFICATION DC BALANCE ADJUSTMENT

1. Set the CH 1 [CH 2] **AC-GND-DC** switch to **GND** and the **VERT/MODE** switch to **CH 1 [CH 2]**.
2. Turn the CH 1 [CH 2] **VOLTS/DIV VAR** knob to **CAL** and the **VOLTS/DIV** setting to **10 mV**.
3. Position the trace to the horizontal center line.
4. Pull out the **VOLTS/DIV VAR** knob and adjust VR104 [VR204] (MAG DC) for a trace at the horizontal center line.
5. Push the **VOLTS/DIV VAR** knob back to its normal position.
6. Repeat steps 3 through 5 until a horizontal center line division shift of less than ± 0.2 is obtained.
7. Repeat procedure for CH 2 using data shown in brackets.

VARIABLE DC BALANCE ADJUSTMENT

1. Set the CH 1 [CH 2] **AC-GND-DC** switch to **GND** and the **VERT MODE** switch to **CH 1 [CH 2]** to display a trace on the CRT screen.
2. Set the **VOLTS/DIV** switch to **10 mV**.

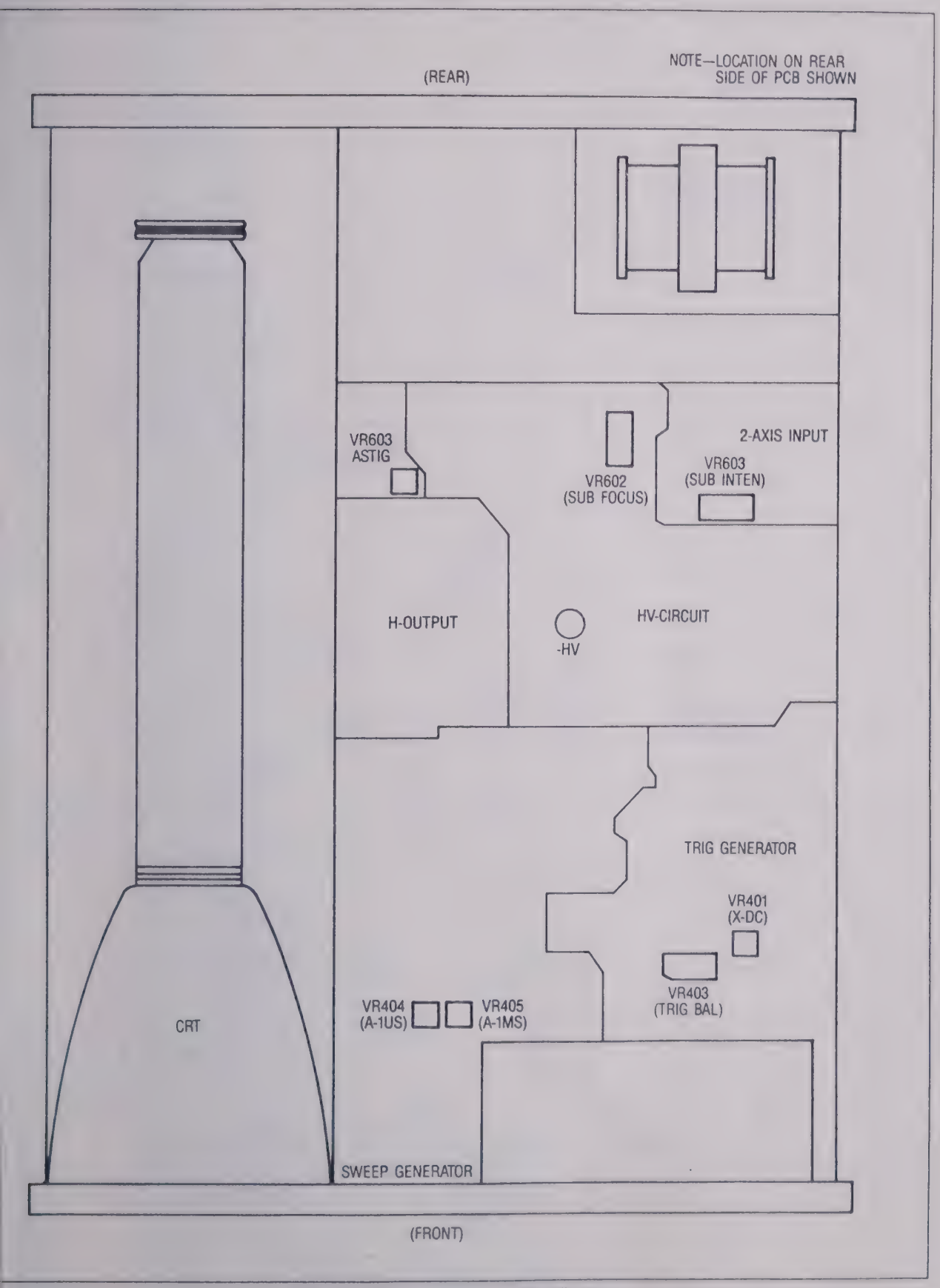


Fig. 1. Adjustment Locations (Top View)

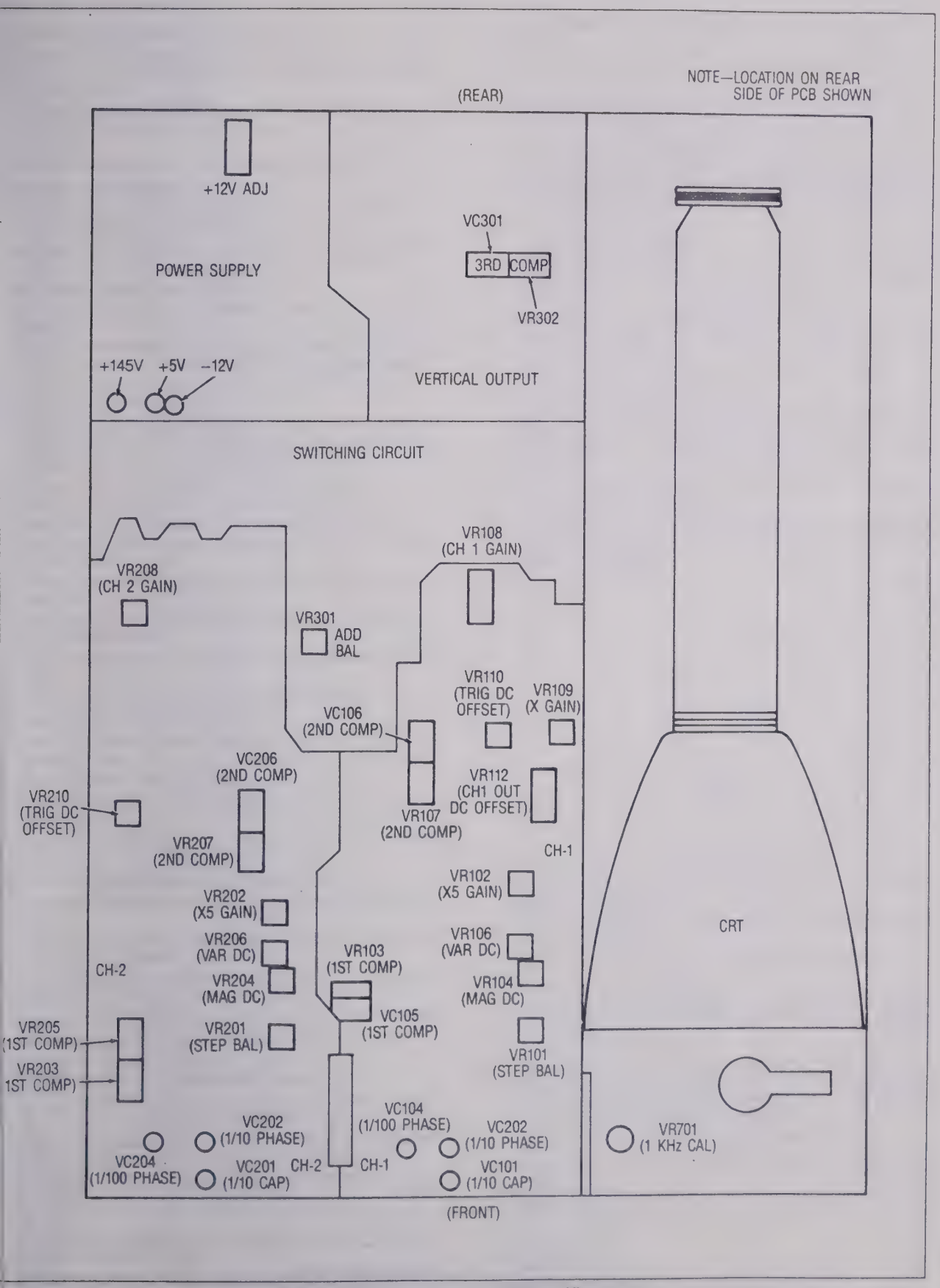


Fig. 2. Adjustment Locations (Bottom View)

Position the trace to the horizontal center line.

Turning the **VAR** knob from left to right adjust VR106 [VR206] (VAR DC) until a horizontal center line division shift of less than ± 0.3 is obtained.

Pull out the **VOLTS/DIV VAR** knob and observe the shift of the trace. The shift division must be within ± 0.6 of the horizontal center line.

Repeat procedure for CH 2 using data shown in brackets.

D BALANCE ADJUSTMENT

Set both the CH 1 and CH 2 **AC-GND-DC** switches to **GND** and both **VOLTS/DIV** switches to **10 mV**.

Set the **VERT MODE** switch separately to the **CH1** and **CH2** positions to position the trace to the horizontal center line.

Set the **VERT MODE** switch to **ADD**.

Adjust VR301 (ADD BAL) to position the trace to the horizontal center line.

Set the **VERT MODE** switch to each position (**CH1, CH2, DUAL**) The trace division must be within ± 0.5 of the center horizontal line.

NSITIVITY CALIBRATION

Set both CH 1 and CH 2 **VOLTS/DIV** switches to **10 mV**. Turn both **VOLTS/DIV VAR** knobs to **CAL** and set both **AC-GND-DC** switches to **DC**. Set the **VERT MODE** switch to **CH 1**.

Connect the standard amplitude calibrator to both the input connectors and set for a 50 mV p-p square-wave signal.

Adjust VR108 (CH 1 GAIN) for a display of five divisions.

Set the **VERT MODE** switch to **DUAL** and both the **AC-GND-DC** switches to **GND**.

Turn the **CH 1 POS** control to position the trace at the horizontal center line.

Pull out and turn the **CH 2 POS** control to position the trace at the horizontal center line.

Set the **VERT MODE** switch to **ADD** and the **AC-GND-DC** switch to **DC**.

Adjust VR208 (CH 2 GAIN) to align the CRT screen.

Set the **VERT MODE** switch to **CH 1**.

Set the standard amplitude calibrator for an eight division 50 kHz sinewave signal.

Set the **TIME/DIV** switch to **0.2 mS**.

Set the **VERT MODE** switch to **ADD** and check the division of the AC amplitude.

Repeat steps 4 through 9 as necessary until an AC amplitude division less than 0.06 is obtained.

MAGNIFICATION SENSITIVITY CALIBRATION

Set the **VOLTS/DIV** switch to **10 mV** and the input coupling switch to DC.

Turn both the **VOLTS/DIV VAR** knobs to **CAL** and pull out the knob to set the **X5 MAG**.

Connect the standard amplitude calibrator to the input connectors and set for a 10 mV p-p 1 kHz square-wave signal.

Adjust VR102 [VR202] (X5 MAG GAIN) for a five division display.

Repeat procedure for CH 2 using data shown in brackets.

UARE-WAVE CHARACTERISTIC
JUSTMENT/FREQUENCY RESPONSE CHECK

Set both the **VOLTS/DIV** switches to **10 mV**, the **TIME/DIV** switch to **0.2 µS**, and both **AC-GND-DC** switches to **AC**.

Using a 50Ω termination and cable, connect the 20 MHz sinewave signal to CH 1 [CH 2] input to get a four division display.

Adjust VC105 [VC205] (1ST COMP) and VC106 [VC206] (2ND COMP) for the maximum amplitude of signal wave on the CRT screen.

Using a digital multimeter (DMM), Adjust VR107 [VR207] (2ND COMP) to get a 90Ω reading.

Using a 50Ω termination and cable, connect the fast-rise positive output (1 MHz) of the square-wave generator to the input.

Adjust the square-wave generator output for a six division display.

7. Adjust VR302 and VC301 (3RD COMP) so that the square-wave is flat.
8. Readjust VR107 [VR207] (2ND COMP) to get a flat (top) square-wave form.
9. Readjust VR103 [VR203] (1ST COMP) for an overshoot of 0.1 division and ringing of waveform of less than 0.3 division.
10. Connect the sinewave generator to the input connectors and set for a 100 kHz, 80 mV p-p, eight division display.
11. Change only the frequency of the sinewave generator to 43 MHz. The amplitude of the sinewave on the CRT screen must be above 5.6 division display.
12. Pull out the **VOLTS/DIV VAR** knob to set at **X5 MAG**. Turn the **VOLTS/DIV** switch to **5 mV**.
13. Set the sinewave generator for a 100 KHz, 8 mV p-p, eight division display signal.
14. Change only the frequency of the sinewave generator to 21 MHz. The amplitude of the sinewave on the CRT screen must be above a 5.6 division display.
15. Repeat procedure for CH 2 using data shown in brackets.

PHASE COMPENSATION ADJUSTMENT

1. Set the CH 1 [CH 2] **VOLTS/DIV** switch to **0.1 V**. Set the CH 1 [CH 2] **AC-GND-DC** switch to **DC**. Set the **VERT MODE** switch to **CH 1 [CH 2]**. Turn the **VOLTS/DIV VAR** knob of CH 1 [CH 2] to **CAL**.
2. Set the oscilloscope calibration generator for a 0.5 V, five division display square-wave signal.
3. Adjust trimmer capacitor VC102 [VC202] (1/10 PHASE) for a square-wave that is an ideal waveform. (See Fig 3 for Square Wave Characteristics)

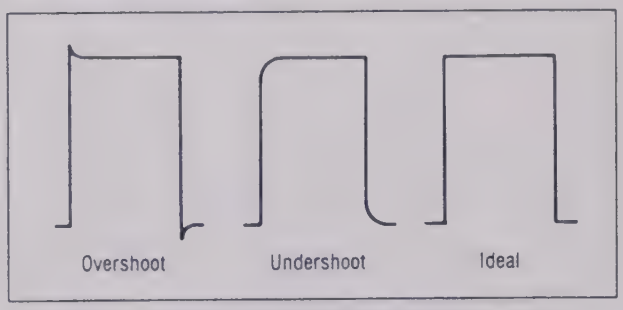


Fig. 3. Adjusting 1 kHz Square Wave Characteristics

4. Change the CH 1 [CH 2] **VOLTS/DIV** switch to **1 V**.
5. Set the oscilloscope calibration generator for a 5 V, five division display square-wave signal.
6. Adjust trimmer capacitor VC104 [VC204] (1/100 PHASE) for an ideal square-wave form.
7. Repeat procedure for CH 2 using data shown in brackets.

INPUT CAPACITY ADJUSTMENT

1. Set the CH 1 [CH 2] **VOLTS/DIV** switch to **10 mV**. Set the **VERT MODE** switch to CH 1 [CH 2]. Set the CH 1 [CH 2] **AC-GND-DC** switch to **DC**.
2. Connect the oscilloscope calibration generator through the 10: 1 probe to the input connector. Set for a 1 kHz, 500 mV, five division display square-wave signal. Then, adjust the trimmer capacitor of the probe for an ideal square-wave form.
3. Change the CH 1 [CH 2] **VOLTS/DIV** switch to **0.1 V**.
4. Adjust the oscilloscope calibration generator for a five division display.
5. Adjust trimmer capacitor VC101 [VC201] (1/10 CAP) for an ideal square-wave form.
6. Same as 3 but 1 V.
7. Same as 4.
8. Same as 5 but VC103 [VC203] (1/100 CAP).
9. Repeat procedure for CH 2 using data shown in brackets.

MEBASE ADJUSTMENT

WEEP TIME CALIBRATION

Set the **TIME/DIV** switch to **1 mS**. Turn the **SWEEP/VAR** knob to **CAL**. Set the **VERT MODE** switch to **CH 1**.

Set the time mark generator to 1 mS (1 kHz pulse train) time marks.

Adjust VR405 (A-1 mS) so that the time marks coincide with the middle eight graticule lines.

Change the **TIME/DIV** switch to **1 µS**. Change the time mark generator for 1 uS time marks.

Adjust VR404 (A-1 µS) so that the time marks coincide with the middle eight graticule marks.

ORIZONTAL AXIS ADJUSTMENT

AIN ADJUSTMENT

Set the **VOLTS/DIV** switch to **10 mV**. Set the **TIME/DIV** switch to **X-Y**. Set the **COUPLING** switch to **AC**.

Set the CH 1 **AC-GND-DC** Switch to **AC**. Set the **SOURCE** and **VERT MODE** switches to **X-Y**. Turn the CH 1 **VOLTS/DIV VAR** knob to **CAL**.

Connect the oscilloscope calibration generator to the CH 1 input connector, set for 1 kHz, 0.1 V p-p square-wave.

Adjust VR109 (X-GAIN) so that the trace is a ten division display.

Adjust the oscilloscope calibration generator for a two division display.

Pull out the **X5 MAG** control and check that the horizontal trace is within 10 ± 0.3 divisions on the CRT screen.

RIGGER SYSTEM ADJUSTMENT

IGGER DC OFFSET ADJUSTMENT

Set the CH 1 [CH 2] **AC-GND-DC** switch to **AC**. Set the **SOURCE** and **VERT MODE** switches to **CH 1** [**CH 2**]. Set the **COUPLING** switch to **AC**.

Set both the **TIME/DIV** switches to **10 mV**. Set the sinewave generator for a 1 kHz, 80 mV p-p, eight division display signal.

Set the **TIME/DIV** switch to **1 mS**. Turn the CH 1 [CH 2] **POS** control to the midposition.

Turn the **POS** control of **LEVEL** so that the trigger point is brought to the center of the displayed waveform amplitude.

Adjust VR110 [VR210] (TRIG DC OFFSET) until the position of the trigger point is not affected by alternate **AC** and **DC** positions of the **COUPLING** switch.

Repeat procedure for CH 2 using data shown in brackets.

1 DC OFFSET SIGNAL OUTPUT ADJUSTMENT

Set the **VERT MODE** switch to **DUAL** and the **SOURCE** switch to **CH 1**.

Set both the **AC-GND-DC** switches to **GND**.

Set the CH 2 **VOLTS/DIV** switch to **10 mV**. Turn the CH 2 **POS** control to its midposition.

Using a coaxial cable, connect the CH 1 signal output to the CH 2 input terminal.

Change the CH 2 **AC-GND-DC** switch to **DC**.

Adjust VR112 (CH 1 OUT DC OFFSET) so that the trace is within ± 0.2 division of the center horizontal line.

POSITION ADJUSTMENT

Set the **TIME\DIV** switch to **1 mS**.

Align the start point of the sweep with the left hand of the CRT graticule with the **POS** control of **LEVEL**.

Set the **TIME/DIV** switch to **X-Y**.

Adjust VR401 (X-DC) so that the beam spot is positioned at the center of the CRT graticule.

TRIGGER SLOPE BALANCE ADJUSTMENT

1. Set the **VERT MODE** switch to **CH 1**.
2. Turn the **LEVEL VAR** knob counterclockwise to **FIX**.
3. Set the **TIME/DIV** switch to **5 mS**.
4. Connect the 1 kHz sinewave signal to the CH 1 input to get a 0.4 division display on the CRT screen.
5. Adjust VR403 (TRIG BAL) until the signal waveform has a steady and inverse waveform on the CRT screen when the operation is switched between + SLOPE and – SLOPE. (See example in Figs. 4 & 5)

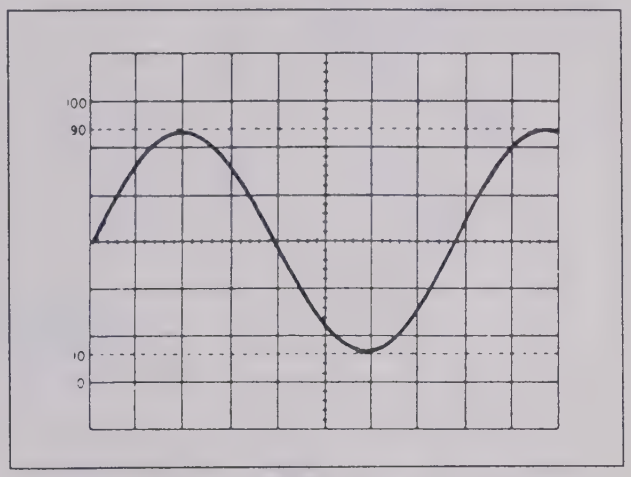


Fig. 4. Adjusting Trigger Point

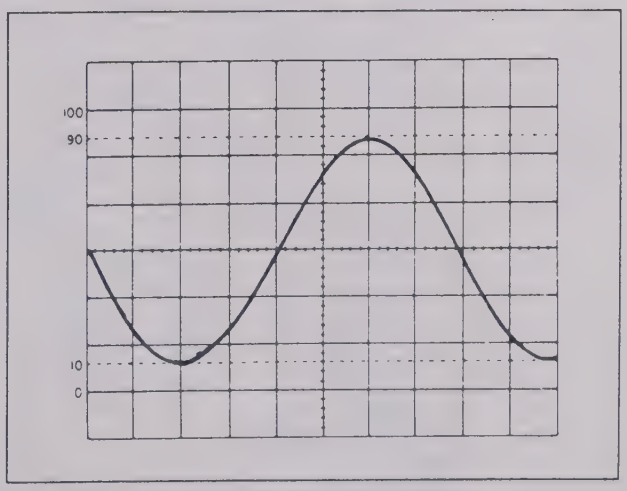
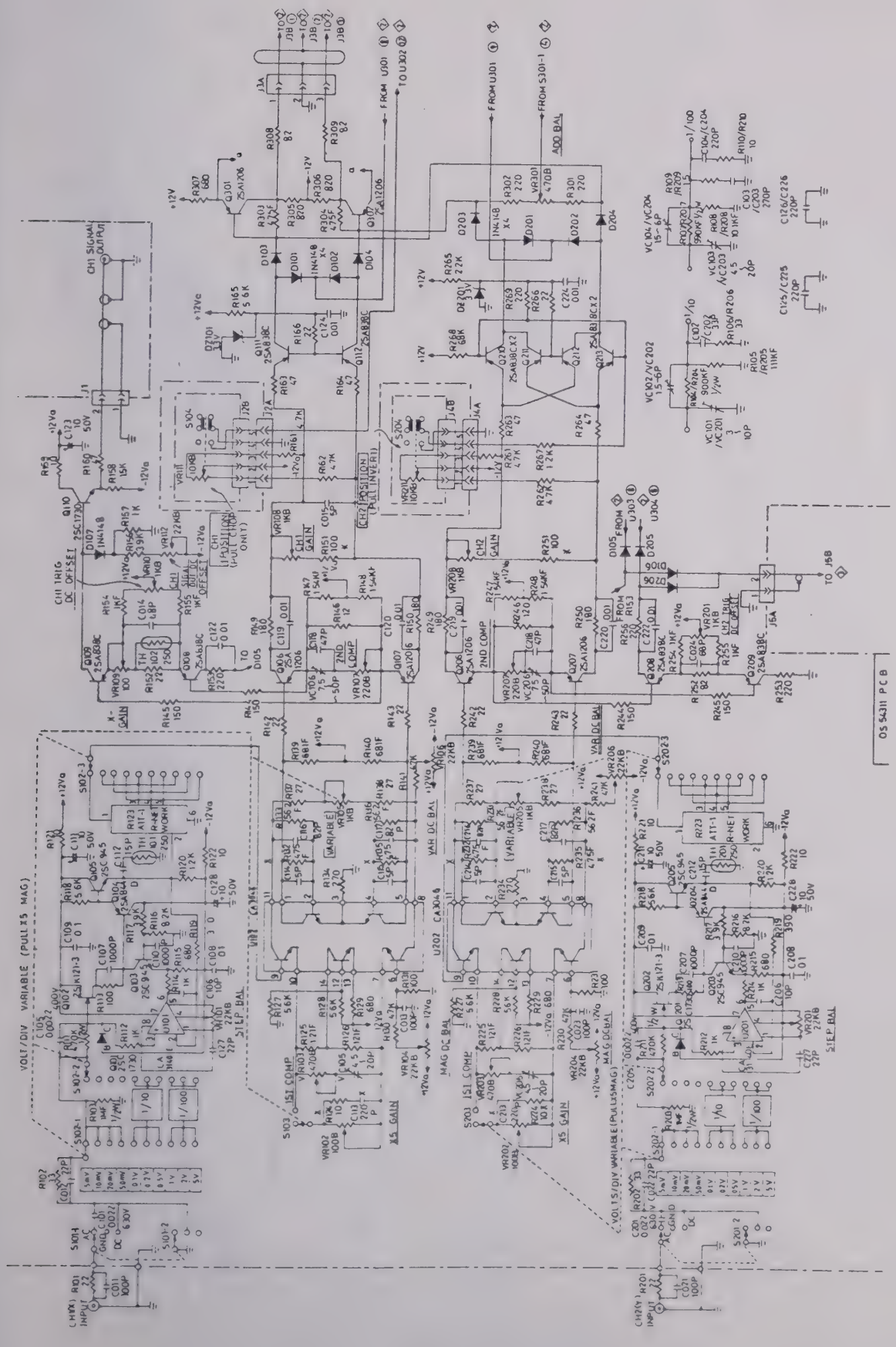


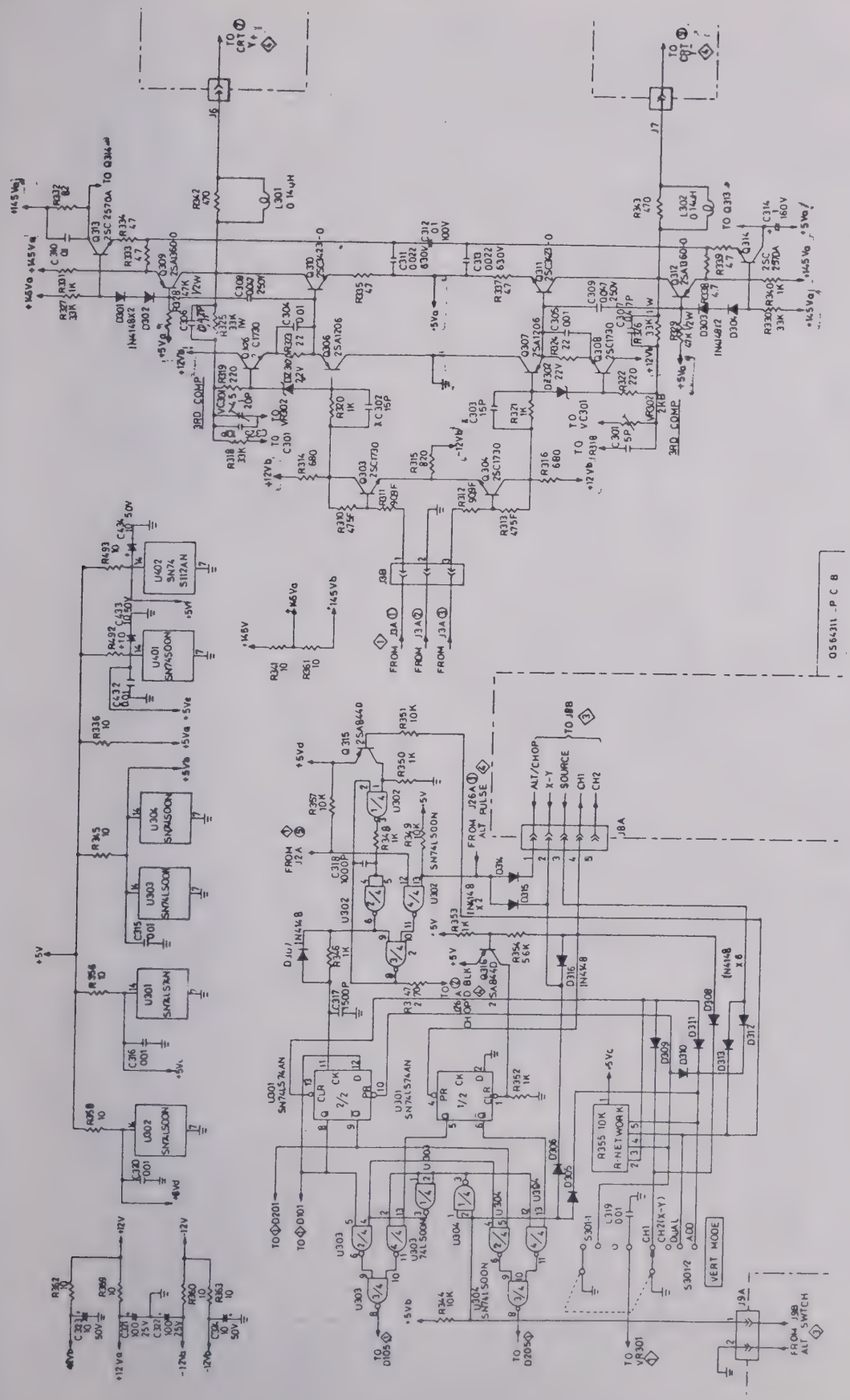
Fig. 5. Adjusting Trigger Point

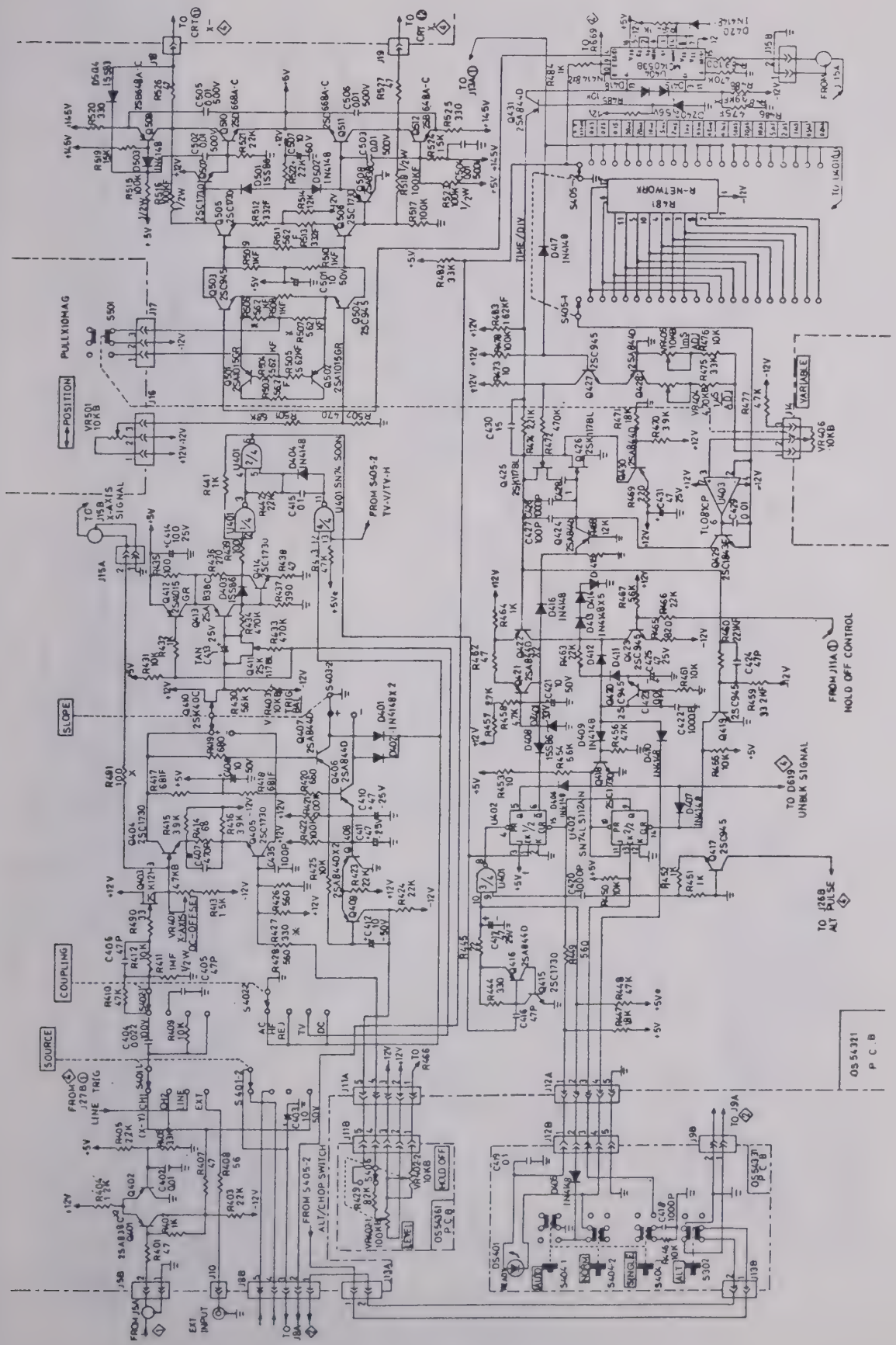
CALIBRATOR OUTPUT ADJUSTMENT

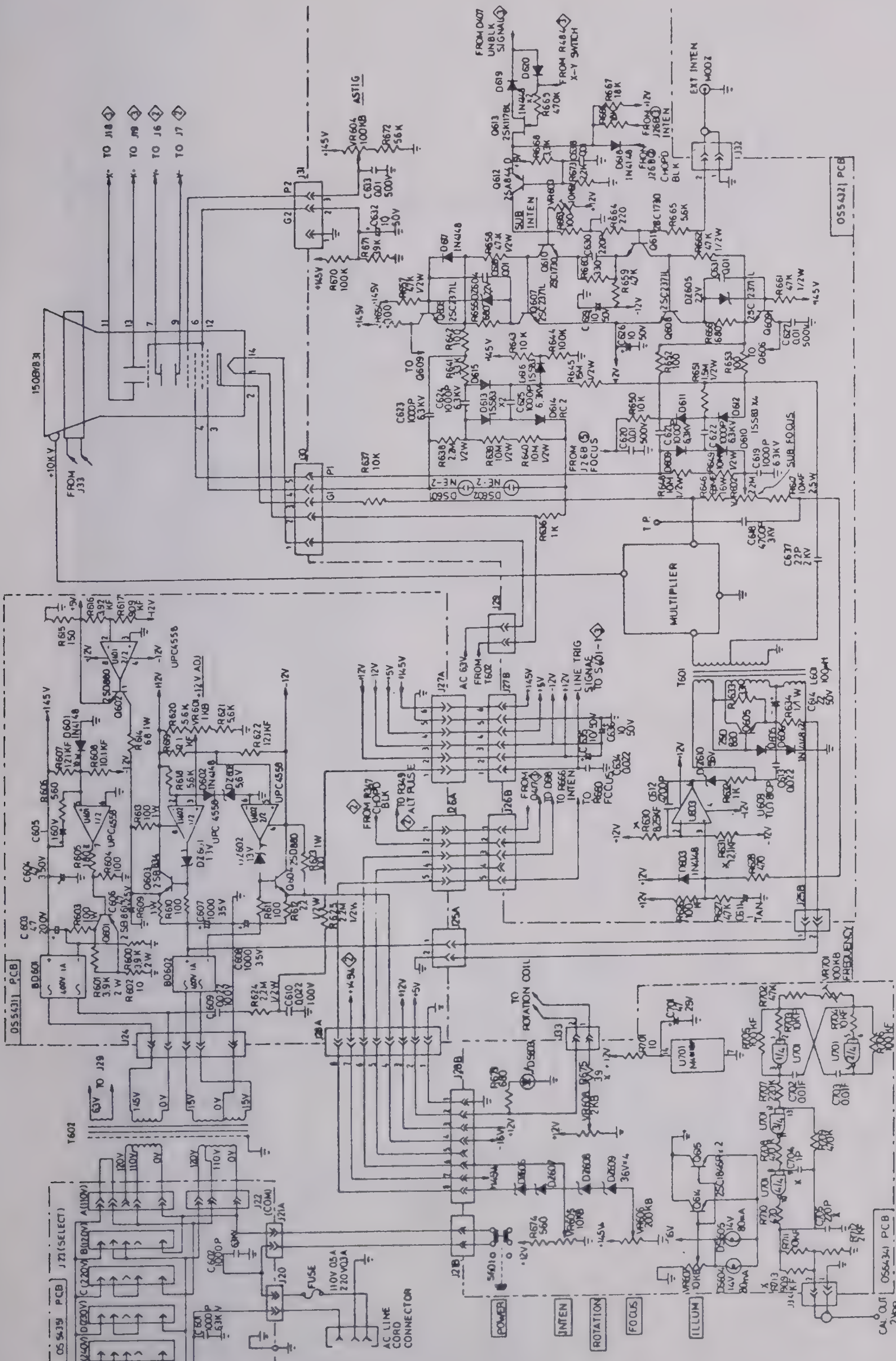
CAL TERMINAL ADJUSTMENT

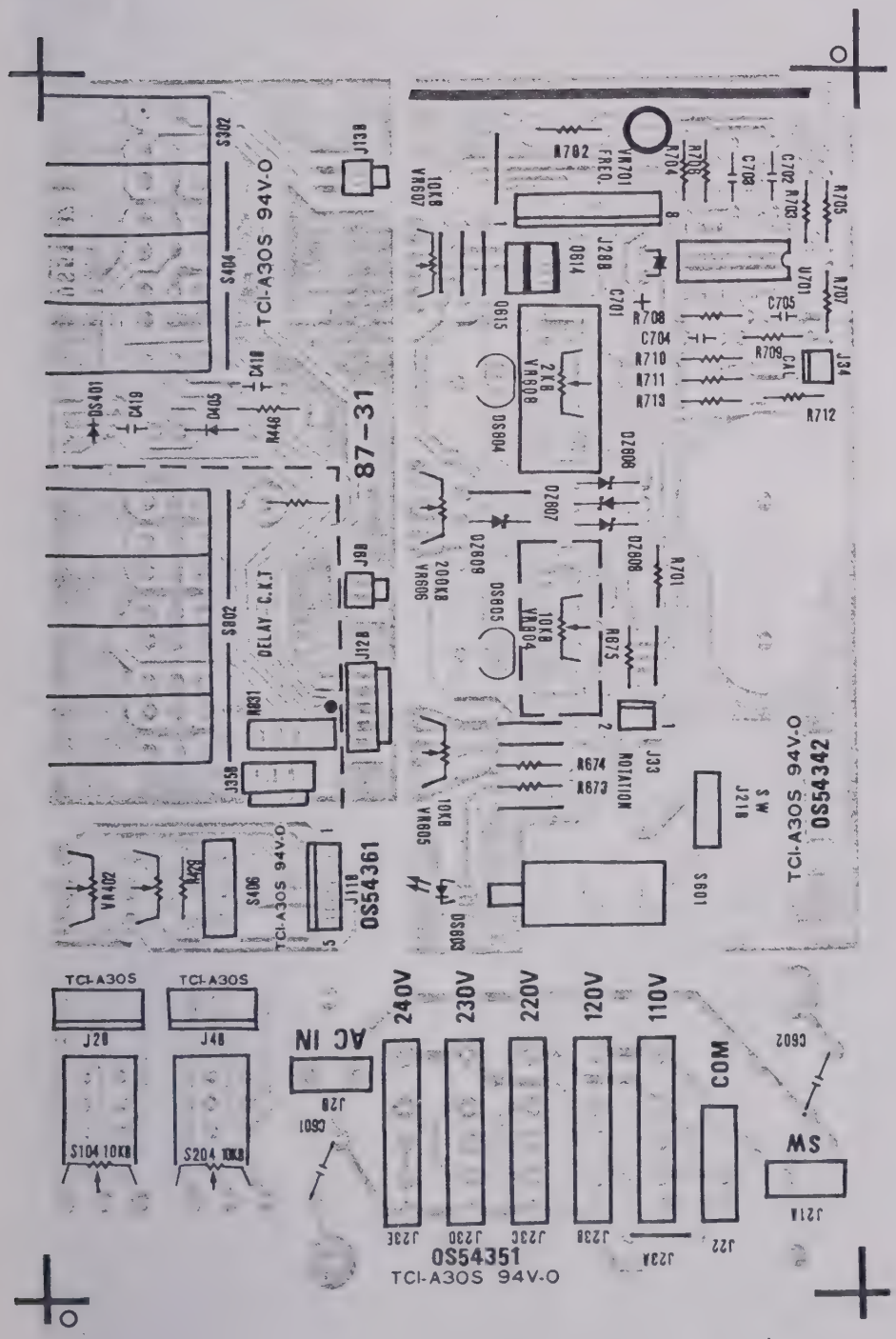
1. Set the **VERT MODE** switch to CH 1.
2. Set the CH 1 **AC-GND-DC** switch to **DC**. Set the CH 1 **VOLTS/DIV** switch to **0.5 V**.
3. Set the **TIME/DIV** switch to **0.1 mS**.
4. Using a coaxial cable, connect the CAL signal output to the CH 1 input terminal.
5. Adjust VR701 (1 kHz CAL) for a one-cycle Square-wave waveform aligned with the ten division graticule lines.

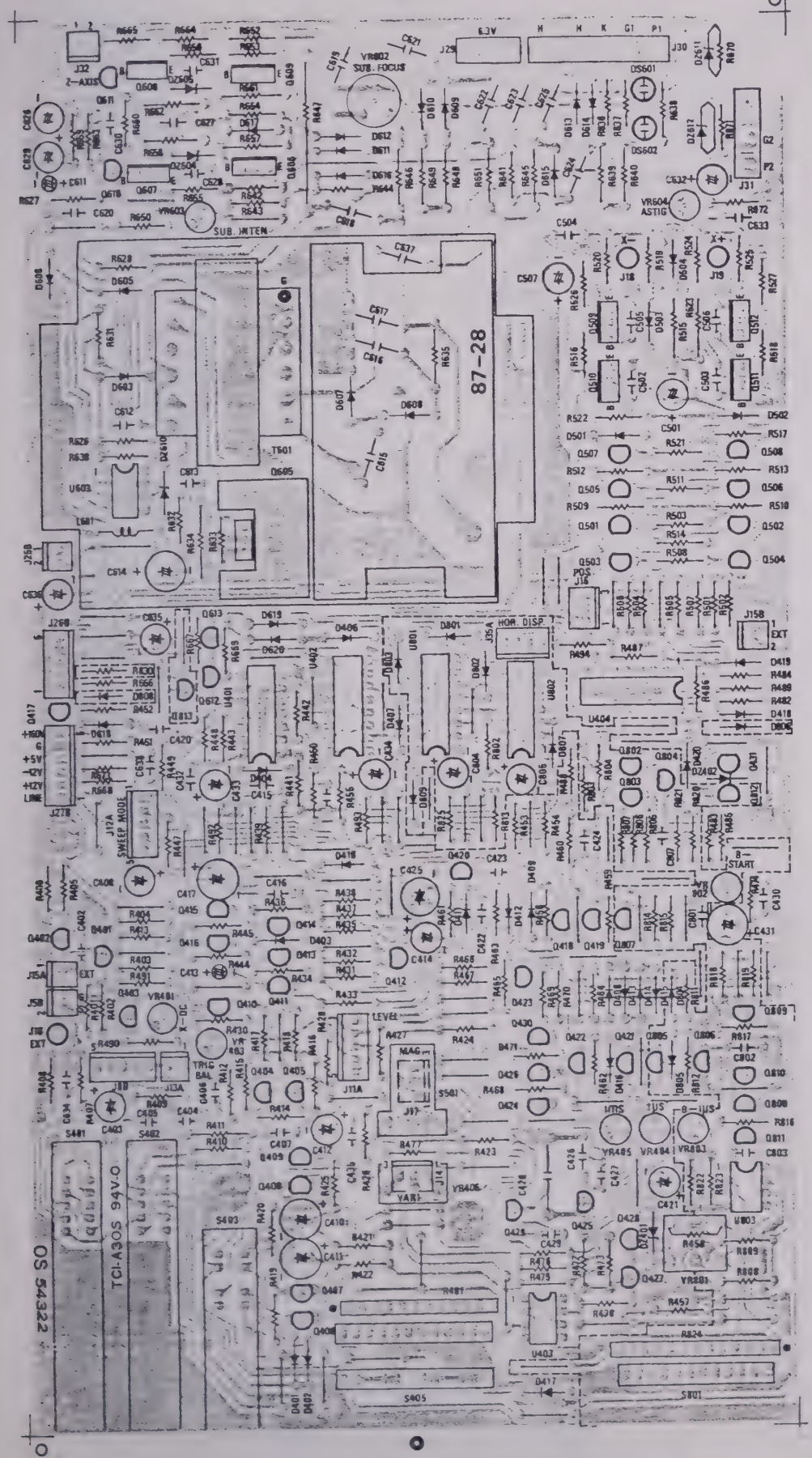

VOLT/DIV VARIABLE (PULL X5 MAG)
CH1 SIGNAL OUTPUT
CH1 TRIG DC OFFSET
CH1 POSITION (PULL INVERT ONLY)
CH2 POSITION (PULL INVERT)
CH1 GAIN
CH2 GAIN
2ND COMP
X-GAIN
VAR DC BAL
ADD BAL
ISI COMP
X5 GAIN
MAG DC BAL
MAG DC BAL
STEP BAL
VOLTS/DIV VARIABLE (PULL X5 MAG)
CH1 (X) INPUT
CH2 (Y) INPUT
OS 5411 PC B

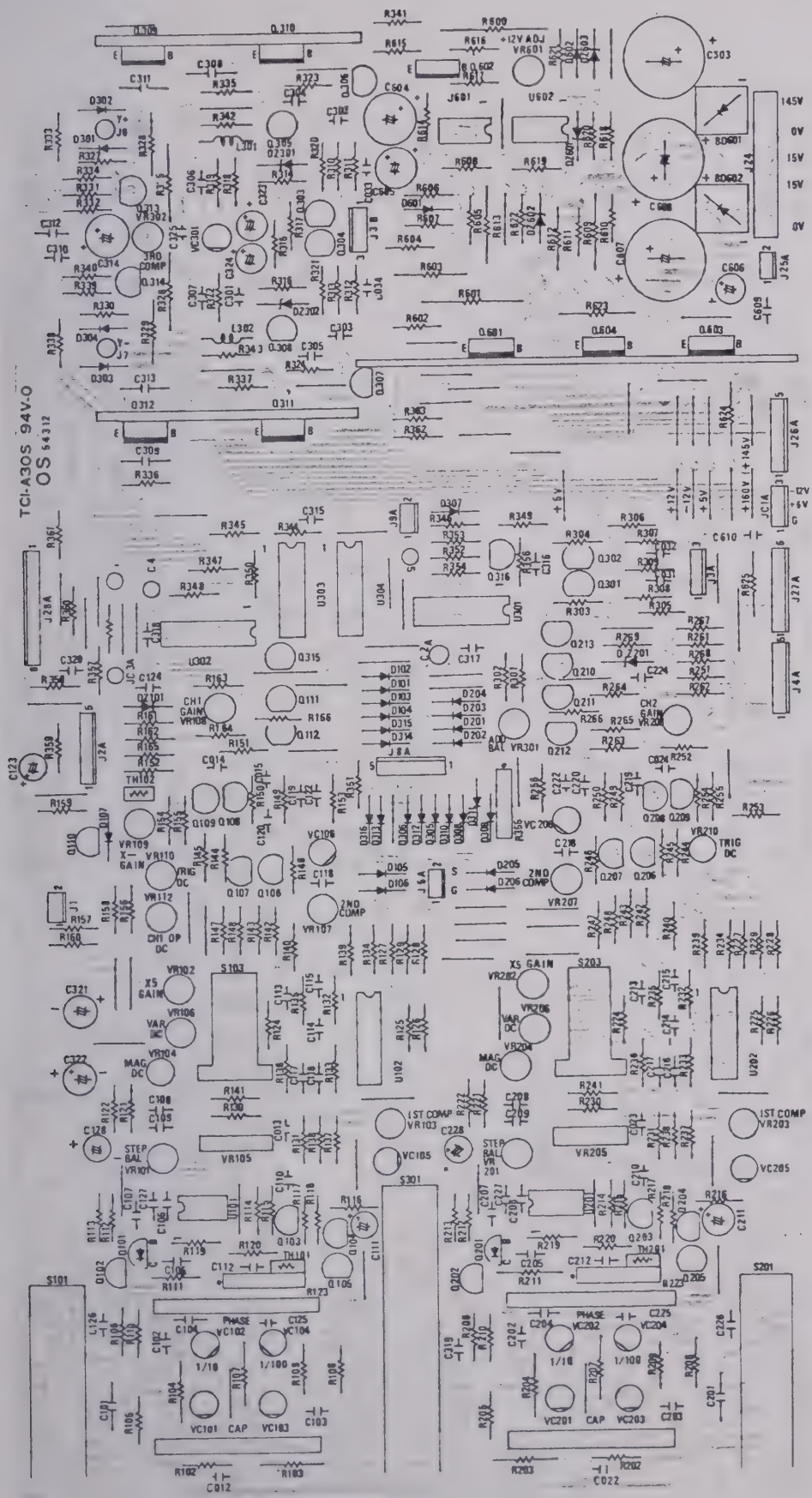

3RD COMP
VERT MODE
R-NETWORK
ALT/CHOP
X-Y
SOURCE
CH1
CH2
FROM J26A ALT PULSE
FROM J9B ALT SWITCH
Q564311 - P C B


SOURCE
COUPLING
SLOPE
POSITION
PULLXIOMAG
VARIABLE
TIME/DIV
R-NETWORK
HOLD OFF CONTROL
UNBLK SIGNAL
ALT PULSE
ALT/CHOP SWITCH
EXT INPUT
LINE TRIG
FROM J15A
FROM J15B
FROM J27B
FROM J11A
FROM J15A
TO J9A
TO J13A
TO J26B
TO D619
TO J13A
TO J14A
TO CRT
OS54321 P.C.B
OS54361 P.C.B
OS54331 P.C.B
HOLD OFF
LEVEL
AUTO
NORM
SINGLE
ALT


150BYB31
+10KV
FROM J33
TO J18
TO J19
TO J6
TO J7
ASTIG
VR604 100KB
R672 56K
C633 0.01 500V
C632 10 50V
R671 39K
R670 100K
FROM D407 UNBLK SIGNAL
FROM R484 X-Y SWITCH
D619
D620
Q613 2SK117BL
Q612 2SA844
R669 470K
R667 18K
SUB INTEN
D616 1N4148
FROM J26B CHOPD BLK
FROM +12V J26B INTEN
EXT INTEN
J32
OS54321 PCB
R665 5.6K
R664 220
R662 47K 1/2W
R661 47K 1/2W
DZ605 22V
C627 0.01 500V
R659 47K
D617 1N4148
R658 47K 1/2W
Q607 2SC2371L
Q610 2SC1730
Q611 2SC1730
C630 220P
R652 100
R653 100
R651 1.5M 1/2W
R650 10K
C620 0.01 500V
D611
D612
D610 1SS83 x4
C621 1000P 6.3KV
C622 1000P 6.3KV
C619 1000P 6.3KV
SUB FOCUS
FROM J26B FOCUS
R645 15M 1/2W
R644 100K
R643 10K
D614 RC2
D613 1SS83 x2
C625 1000P 6.3KV
C624 1000P 6.3KV
C623 1000P 6.3KV
D615
R641 33K
R642 100
TO Q609
R638 2.2M 1/2W
R639 10M 1/2W
R640 10M 1/2W
R637 10K
DS601 NE-2
DS602 NE-2
R636 1K
T.P.
C648 4700P 3KV
C637 22P 2KV
MULTIPLIER
T601
L601 100μH
C614 22 50V
R634 1/1 W
R633
Q605
D605
D606
C613 0.022
U603 TL071CP
R632 1K
C612 2200P
R630 8.25KF
R631 12.1KF
R628 470
D603 1N4148
R627 47K
C611 1 TAN
J25B
FREQUENCY
VR701 100KB
OS54311 PCB
BD601
BD602
R615 150
R616 392 KF
R617 909 KF
UPC4558
Q602 2SD880
+12V ADJ
VR601 1KB
R620 5.6K
R621 5.6K
R622 121KF
R614 6.8 1W
R607 121KF
R608 10.1KF
D601 1N4148
C605 160V
R606 560
R605
R604 100
R613 100 1W
R618 5.6K
D602 1N4148
DZ603 5.6V
DZ601 11V
DZ602 13V
Q604 2SD880
R623 1W
Q603 2SB834
Q601 2SB861
C603 47 200V
R603 100 1W
R601 3.9K 2W
R602 10
R600 3.9K 2W
R610 100
R611 100
R612 22
C607 1000 35V
C608 1000 35V
C609 0.022 100V
R624 2.2M 1/2W
R625 2.2M 1/2W
C610 0.022 100V
J24
J28A
J28B
J25A
J27A
J27B
J26A
J26B
J29
AC 63V FROM T602
LINE TRIG SIGNAL TO S401-1
FROM R347 CHOPD BLK
TO R349 ALT PULSE
FROM Q407
TO D818
TO R666 INTEN
TO R660 FOCUS
C634 0.022
C635 10 50V
C636 10 50V
TO ROTATION COIL
J33
R675 39
VR608 2KB
DS603
R673 680
R701 10
U701
C701 47 25V
R702 47K
R703 10KF
R704 10KF
R705 100KF
R706 100KF
C702 0.01F
C703 0.01F
R707 220K
R708 470K
R709 470K
R710 470
R711 10K
R712 2.1KF
C704 1P
C705 220P
R713 909KF
J34
CAL OUT 2Vpp
OS54341 PCB
Q614
Q615
2SC1846R x 2
DS604 14V 80mA
DS605 14V 80mA
VR607 10KB
VR606 200KB
VR605 10KB
R674 560
DZ606
DZ607
DZ608
DZ609 36V x 4
S601
POWER
INTEN
ROTATION
FOCUS
ILLUM
T602
63V TO J29
145V
0V
15V
120V
110V
J21 (SELECT)
A (110V)
B (120V)
C (220V)
D (230V)
E (240V)
J22 (COM)
J21A
J21B
J20
FUSE
110V 0.5A
220V 0.3A
C602 1000P
C601 1000P 6.3KV
AC LINE CORD CONNECTOR
OS54351 PCB


TCI-A30S 94V-O
87-31
DELAY C.K.T
OS54361
TCI-A30S 94V-O
OS54342
TCI-A30S 94V-O
FREQ.
MOTATION
SW
COM
AC IN
240V
230V
220V
120V
110V
TCI-A30S
TCI-A30S
OS54351
TCI-A30S 94V-O


87-28
SUB. FOCUS
SUB. INTEN
HOR. DISP.
SWEEP MODE
LEVEL
START
TCI-A30S 94V-0
OS 54322


TCI-A30S 94V-0
OS 64312
145V
0V
15V
15V
0V
+12V ADJ
VR601
3RD COMP
CH1 GAIN
VR108
CH2 GAIN
VR208
ADD BAL
VR301
X-GAIN
VR109
VR110
VR112
CH1 OP DC
2ND COMP
VR107
TRIG DC
X5 GAIN
VR102
VR106
VR104
MAG DC
VR105
STEP BAL
VR107
1ST COMP
VR103
VC105
S301
S101
S103
S203
S201
PHASE
VC102
VC104
VC101
CAP
VC103
VC202
VC204
VC201
VC203
1/10
1/100

89713